8.2 *z* Test for a Mean

The *z* test is a statistical test for the mean of a population. It can be used when $n \geq 30$, or when the population is normally distributed and σ is known.

The formula for the *z test is*

$$z = \frac{\overline{X} - \mu}{\sigma / \sqrt{n}}$$

where

$\overline{X}$ = sample mean

μ = hypothesized population mean

σ = population standard deviation

n = sample size

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Hypothesis Testing

Section 8-2

Example 8-3

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Example 8-3: Professors' Salaries

A researcher reports that the average salary of assistant professors is more than \$42,000. A sample of 30 assistant professors has a mean salary of \$43,260. At $\alpha = 0.05$, test the claim that assistant professors earn more than \$42,000 per year. The standard deviation of the population is \$5230.

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Step 1: State the hypotheses and identify the claim.

H_0: μ = \$42,000 *and* H_1: μ > \$42,000 (claim)

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Step 1: State the hypotheses and identify the claim.

H_0: μ = \$42,000 *and* H_1: μ > \$42,000 (claim)

Step 2: Find the critical value.

Since α = 0.05 and the test is a right-tailed test, the critical value is z = 1.65.

Example 8-3: Professors' Salaries

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A researcher reports that the average salary of assistant professors is more than $42,000. A sample of 30 assistant professors has a mean salary of $43,260. At $\alpha = 0.05$, test the claim that assistant professors earn more than $42,000 per year. The standard deviation of the population is $5230.

Step 3: Compute the test value.

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$$z = \frac{\bar{X} - \mu}{\sigma / \sqrt{n}}$$

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$$z = \frac{\bar{X} - \mu}{\sigma / \sqrt{n}} = \frac{43260 - 42000}{5230 / \sqrt{30}}$$

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Step 3: Compute the test value.

$$z = \frac{\overline{X} - \mu}{\sigma/\sqrt{n}} = \frac{43260 - 42000}{5230/\sqrt{30}} = 1.32$$

Example 8-3: Professors' Salaries

Step 4: Make the decision.

Since the test value, 1.32, is less than the critical value, 1.65, and is not in the critical region, the decision is to not reject the null hypothesis.

Step 5: Summarize the results.

There is not enough evidence to support the claim that assistant professors earn more on average than $42,000 per year.

Example 8-3: Professors' Salaries

Step 4: Make the decision.

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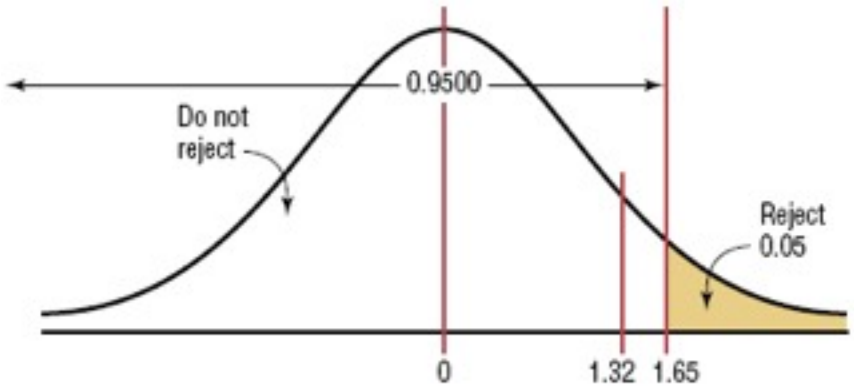

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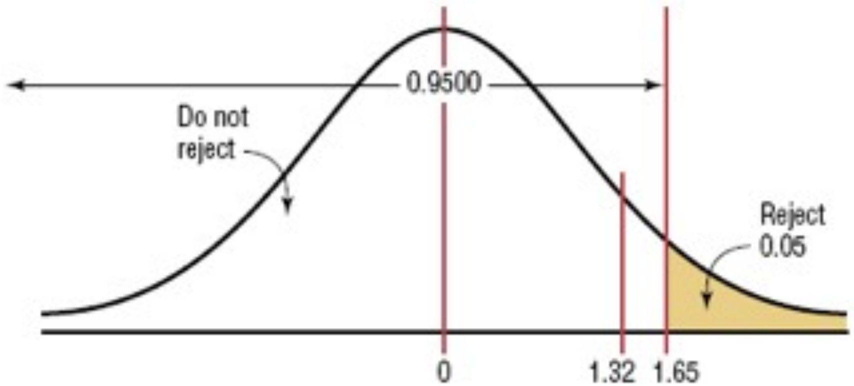

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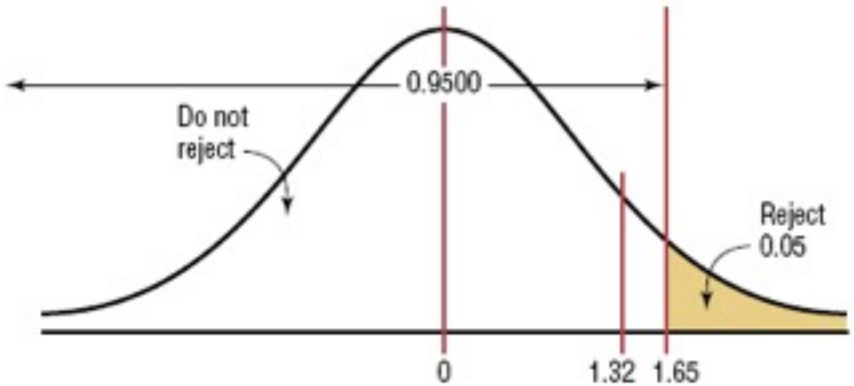

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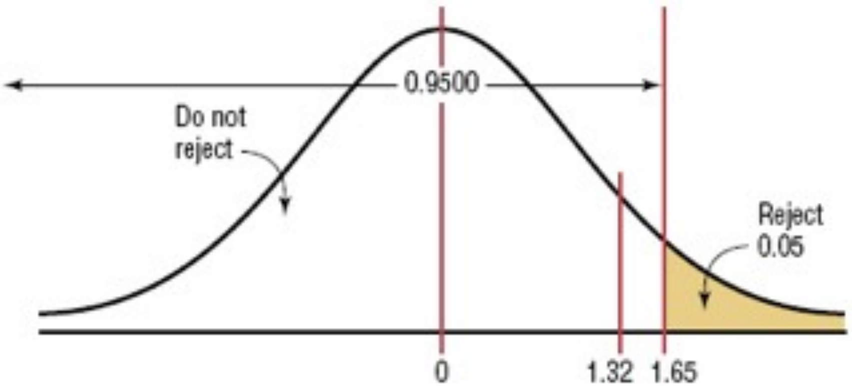

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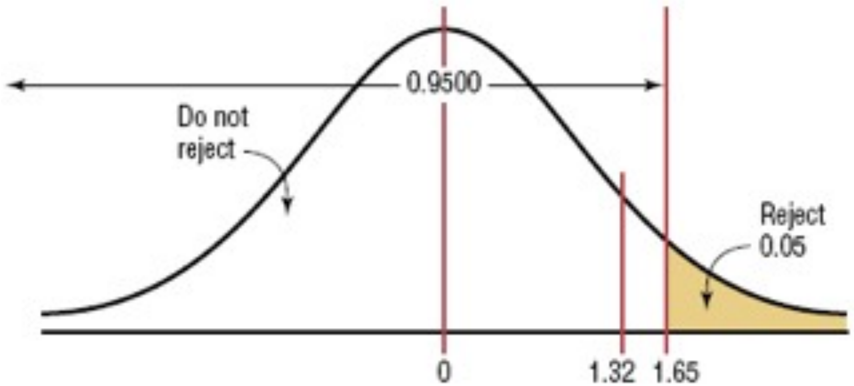

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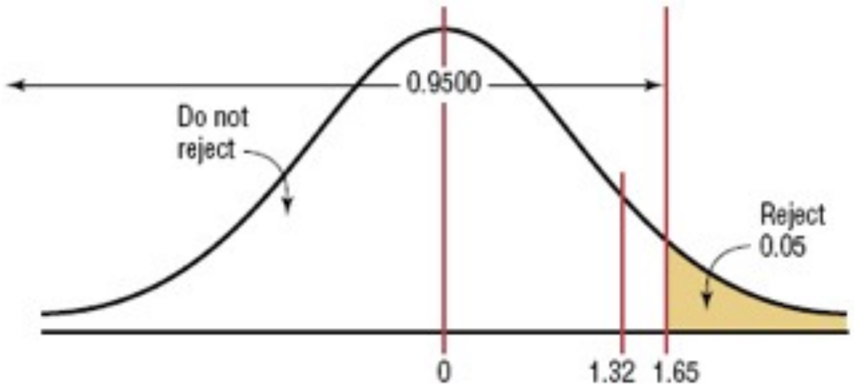

Step 5: Summarize the results.

There is not enough evidence to support the claim that assistant professors earn more on average than $42,000 per year.

Important Comments

- Even though in Example 8–3 the sample mean of \$43,260 is higher than the hypothesized population mean of \$42,000, it is not significantly higher. Hence, the difference may be due to chance.

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- When the null hypothesis is not rejected, there is still a probability of a type II error, i.e., of not rejecting the null hypothesis when it is false.

Important Comments

- Even though in Example 8–3 the sample mean of \$43,260 is higher than the hypothesized population mean of \$42,000, it is not significantly higher. Hence, the difference may be due to chance.
- When the null hypothesis is not rejected, there is still a probability of a type II error, i.e., of not rejecting the null hypothesis when it is false.
- When the null hypothesis is not rejected, it cannot be accepted as true. There is merely not enough evidence to say that it is false.

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Hypothesis Testing

Section 8-2

Example 8-4

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Example 8-4: Cost of Men's Shoes

A researcher claims that the average cost of men's athletic shoes is less than \$80. He selects a random sample of 36 pairs of shoes from a catalog and finds the following costs (in dollars). (The costs have been rounded to the nearest dollar.) Is there enough evidence to support the researcher's claim at $\alpha = 0.10$? Assume $\sigma = 19.2$.

60 70 75 55 80 55 50 40 80 70 50 95

120 90 75 85 80 60 110 65 80 85 85 45

75 60 90 90 60 95 110 85 45 90 70 70

Example 8-4: Cost of Men's Shoes

A researcher claims that the average cost of men's athletic shoes is less than \$80. He selects a random sample of 36 pairs of shoes from a catalog and finds the following costs (in dollars). (The costs have been rounded to the nearest dollar.) Is there enough evidence to support the researcher's claim at $\alpha = 0.10$? Assume $\sigma = 19.2$.

60 70 75 55 80 55 50 40 80 70 50 95

120 90 75 85 80 60 110 65 80 85 85 45

75 60 90 90 60 95 110 85 45 90 70 70

Step 1: State the hypotheses and identify the claim.

H_0: μ = \$80 *and* H_1: μ < \$80 (claim)

Example 8-4: Cost of Men's Shoes

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A researcher claims that the average cost of men's athletic shoes is less than \$80. He selects a random sample of 36 pairs of shoes from a catalog and finds the following costs (in dollars). (The costs have been rounded to the nearest dollar.) Is there enough evidence to support the researcher's claim at $\alpha = 0.10$? Assume $\sigma = 19.2$.

60 70 75 55 80 55 50 40 80 70 50 95

120 90 75 85 80 60 110 65 80 85 85 45

75 60 90 90 60 95 110 85 45 90 70 70

Step 2: Find the critical value.

Since $\alpha = 0.10$ and the test is a left-tailed test, the critical value is $z = -1.28$.

Example 8-4: Cost of Men's Shoes

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Step 3: Compute the test value.

Using technology, we find $\overline{X} = 75.0$ and $\sigma = 19.2$.

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Step 3: Compute the test value.

Using technology, we find $\bar{X} = 75.0$ and $\sigma = 19.2$.

$$z = \frac{\bar{X} - \mu}{\sigma / \sqrt{n}}$$

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Step 3: Compute the test value.

Using technology, we find $\overline{X}$ = 75.0 and σ = 19.2.

$$z = \frac{\overline{X} - \mu}{\sigma / \sqrt{n}} = \frac{75 - 80}{19.2 / \sqrt{36}}$$

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Step 3: Compute the test value.

Using technology, we find $\overline{X}$ = 75.0 and σ = 19.2.

$$z = \frac{\overline{X} - \mu}{\sigma / \sqrt{n}} = \frac{75 - 80}{19.2 / \sqrt{36}} = -1.56$$

Example 8-4: Cost of Men's Shoes

Step 4: Make the decision.

Since the test value, -1.56, falls in the critical region, the decision is to reject the null hypothesis.

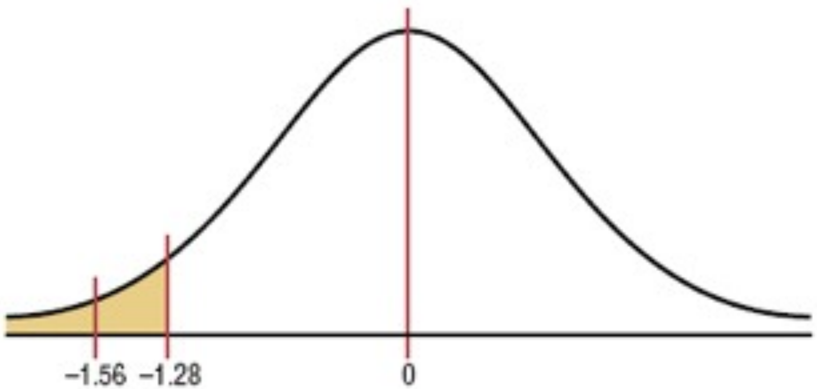
Step 5: Summarize the results.

There is enough evidence to support the claim that the average cost of men's athletic shoes is less than $80.

Example 8-4: Cost of Men’s Shoes

Step 4: Make the decision.

Since the test value, -1.56, falls in the critical region, the decision is to reject the null hypothesis.



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There is enough evidence to support the claim that the average cost of men’s athletic shoes is less than $80.

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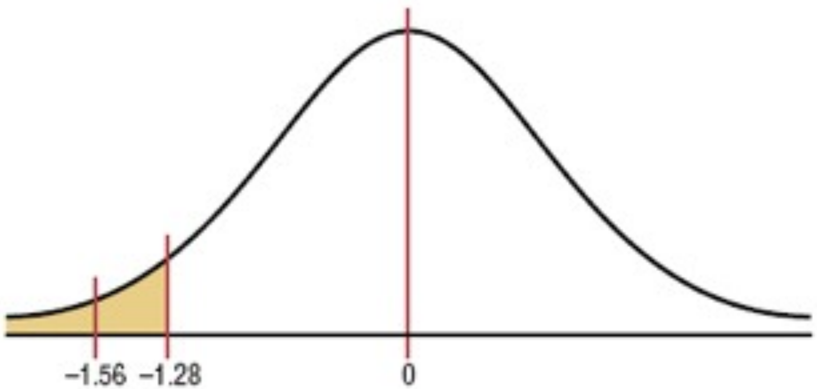

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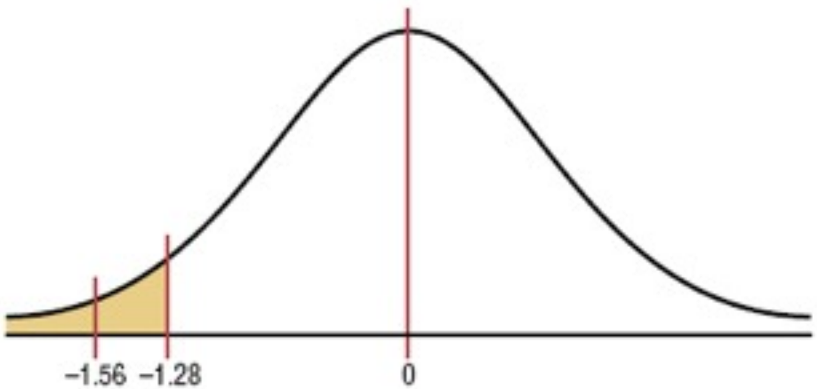

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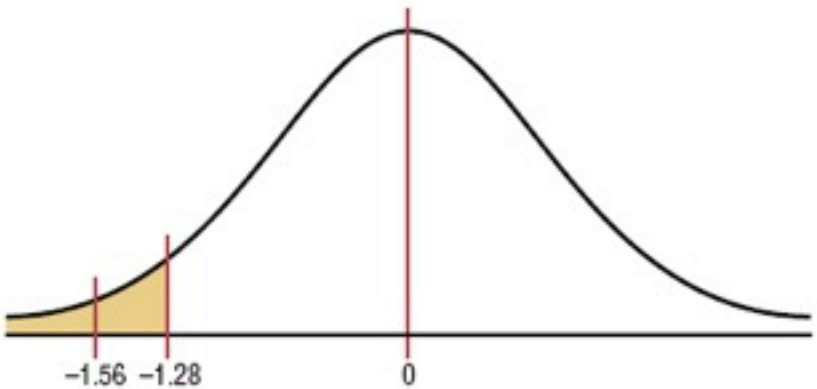

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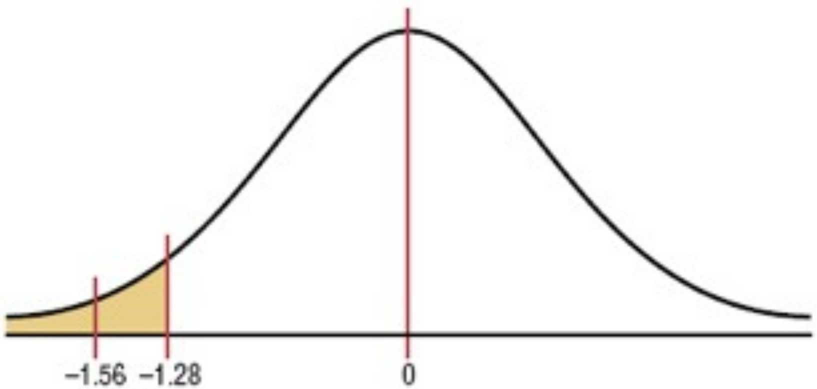

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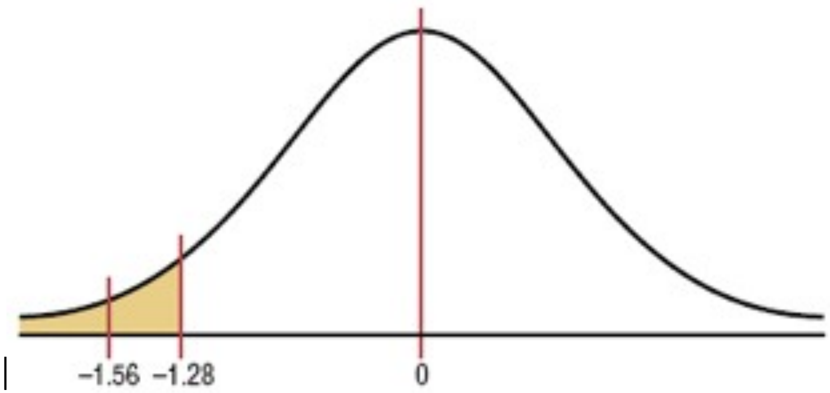

Step 5: Sum

There is enough evidence to support the claim that the average cost of men's athletic shoes is less than $80.

Chapter 8
Hypothesis Testing

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Example 8-5

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Example 8-5: Cost of Rehabilitation

The Medical Rehabilitation Education Foundation reports that the average cost of rehabilitation for stroke victims is \$24,672. To see if the average cost of rehabilitation is different at a particular hospital, a researcher selects a random sample of 35 stroke victims at the hospital and finds that the average cost of their rehabilitation is \$25,226. The standard deviation of the population is \$3251. At $\alpha = 0.01$, can it be concluded that the average cost of stroke rehabilitation at a particular hospital is different from \$24,672?

Example 8-5: Cost of Rehabilitation

The Medical Rehabilitation Education Foundation reports that the average cost of rehabilitation for stroke victims is \$24,672. To see if the average cost of rehabilitation is different at a particular hospital, a researcher selects a random sample of 35 stroke victims at the hospital and finds that the average cost of their rehabilitation is \$25,226. The standard deviation of the population is \$3251. At $\alpha = 0.01$, can it be concluded that the average cost of stroke rehabilitation at a particular hospital is different from \$24,672?

Step 1: State the hypotheses and identify the claim.

H_0: $\mu = \$24,672$ *and* H_1: $\mu \neq \$24,672$ (claim)

Example 8-5: Cost of Rehabilitation

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The Medical Rehabilitation Education Foundation reports that the average cost of rehabilitation for stroke victims is \$24,672. To see if the average cost of rehabilitation is different at a particular hospital, a researcher selects a random sample of 35 stroke victims at the hospital and finds that the average cost of their rehabilitation is \$25,226. The standard deviation of the population is \$3251. At $\alpha = 0.01$, can it be concluded that the average cost of stroke rehabilitation at a particular hospital is different from \$24,672?

Step 2: Find the critical value.

Since $\alpha = 0.01$ and a two-tailed test, the critical values are $z = \pm 2.58$.

Example 8-5: Cost of Rehabilitation

“reports that the average cost of rehabilitation for stroke victims is \$24,672”

“a random sample of 35 stroke victims”

“the average cost of their rehabilitation is \$25,226”

“the standard deviation of the population is \$3251”

“α = 0.01”

Step 3: Find the test value.

Example 8-5: Cost of Rehabilitation

"reports that the average cost of rehabilitation for stroke victims is \$24,672"

"a random sample of 35 stroke victims"

"the average cost of their rehabilitation is \$25,226"

"the standard deviation of the population is \$3251"

"α = 0.01"

Step 3: Find the test value.

$$z = \frac{\bar{X} - \mu}{\sigma / \sqrt{n}}$$

Example 8-5: Cost of Rehabilitation

"reports that the average cost of rehabilitation for stroke victims is \$24,672"

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"the average cost of their rehabilitation is \$25,226"

"the standard deviation of the population is \$3251"

"α = 0.01"

Step 3: Find the test value.

$$z = \frac{\bar{X} - \mu}{\sigma / \sqrt{n}} = \frac{25,226 - 24,672}{3251 / \sqrt{35}}$$

Example 8-5: Cost of Rehabilitation

"reports that the average cost of rehabilitation for stroke victims is $24,672"

"a random sample of 35 stroke victims"

"the average cost of their rehabilitation is $25,226"

"the standard deviation of the population is $3251"

"α = 0.01"

Step 3: Find the test value.

$$z = \frac{\overline{X} - \mu}{\sigma/\sqrt{n}} = \frac{25,226 - 24,672}{3251/\sqrt{35}} = 1.01$$

Example 8-5: Cost of Rehabilitation

Step 4: Make the decision.

Do not reject the null hypothesis, since the test value falls in the noncritical region.

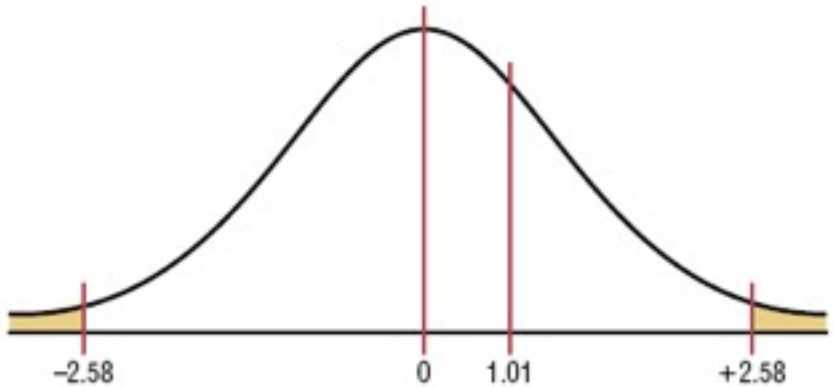
Step 5: Summarize the results.

There is not enough evidence to support the claim that the average cost of rehabilitation at the particular hospital is different from $24,672.

Example 8-5: Cost of Rehabilitation

Step 4: Make the decision.

Do not reject the null hypothesis, since the test value falls in the noncritical region.



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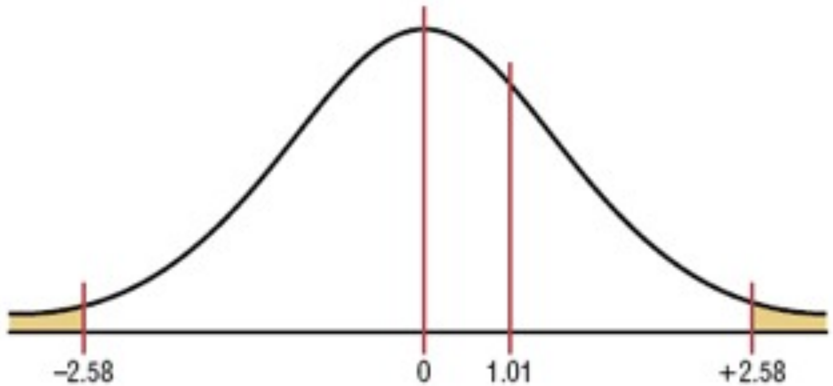

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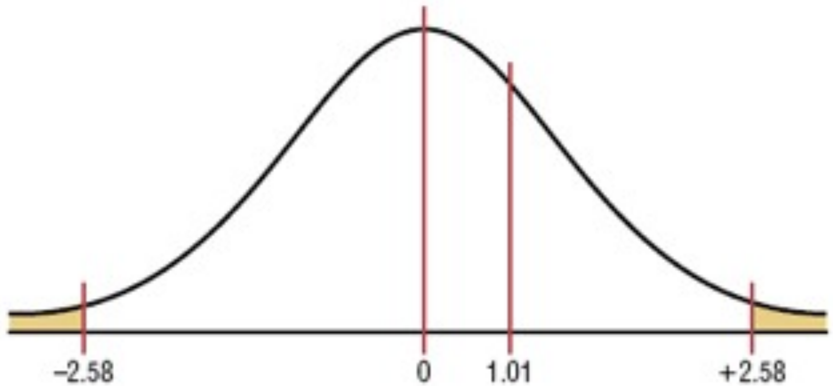

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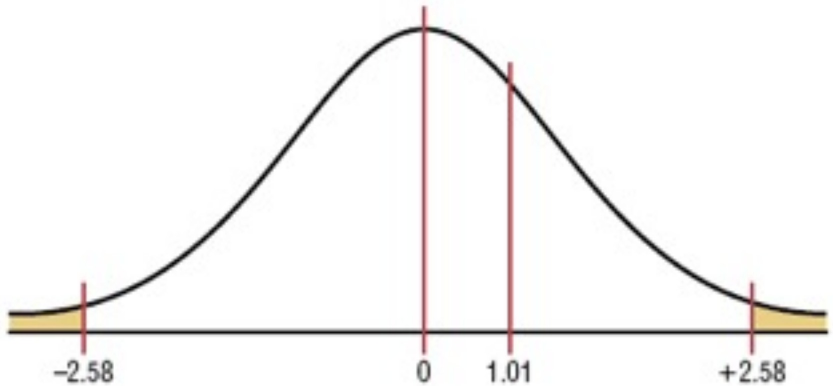

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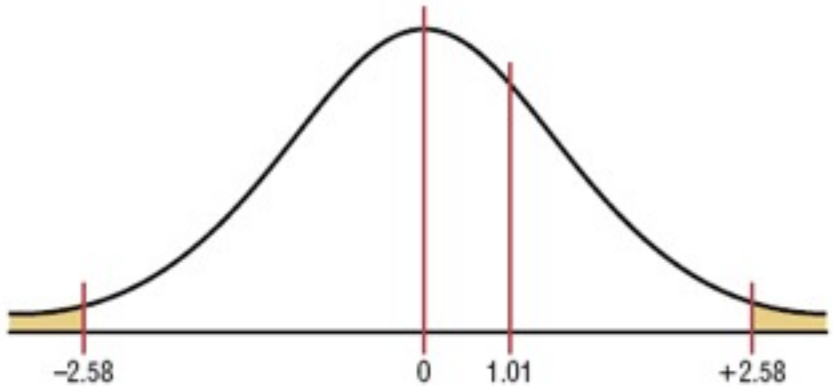

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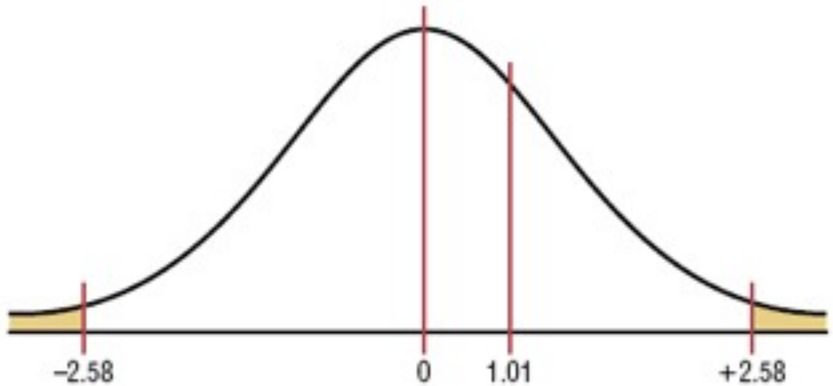

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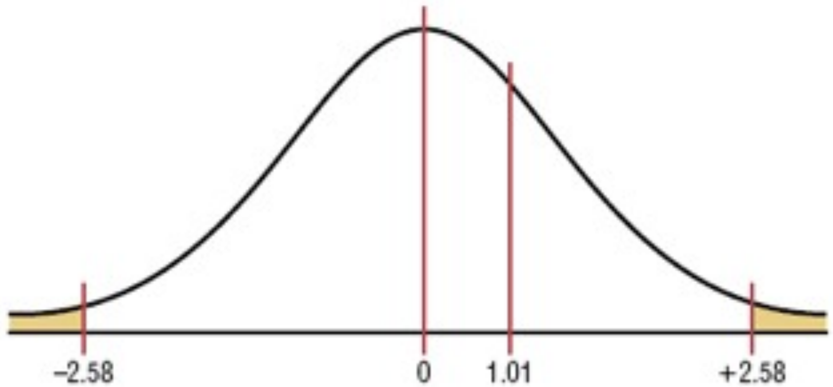
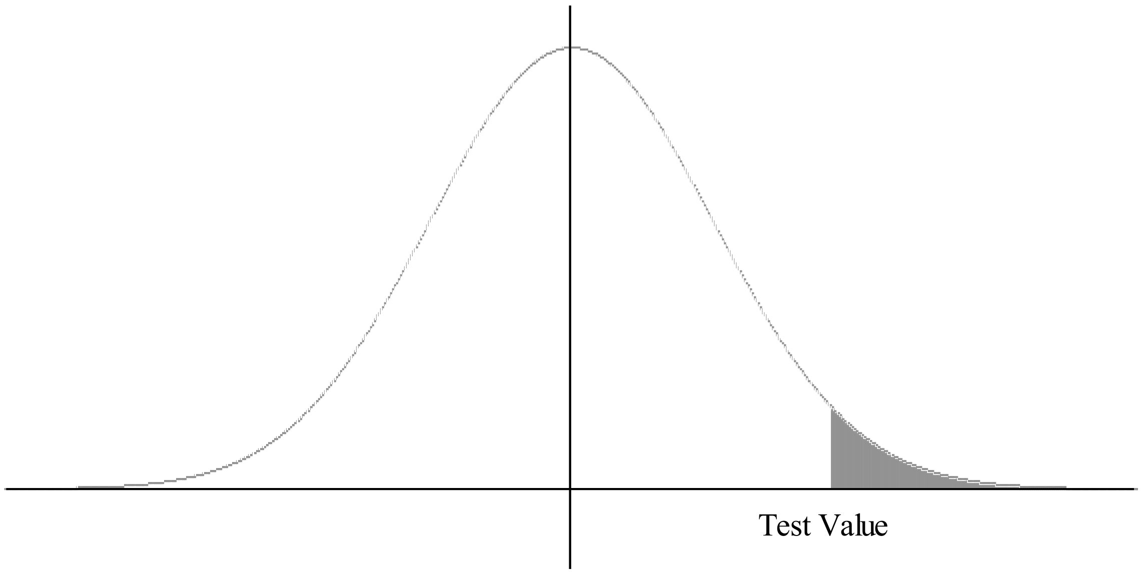


Step 5: Summarize the results.

There is not enough evidence to support the claim that the average cost of rehabilitation at the particular hospital is different from $24,672.

Hypothesis Testing

The ***P*-value** (or probability value) is the probability of getting a sample statistic (such as the mean) or a more extreme sample statistic in the direction of the alternative hypothesis when the null hypothesis is true.



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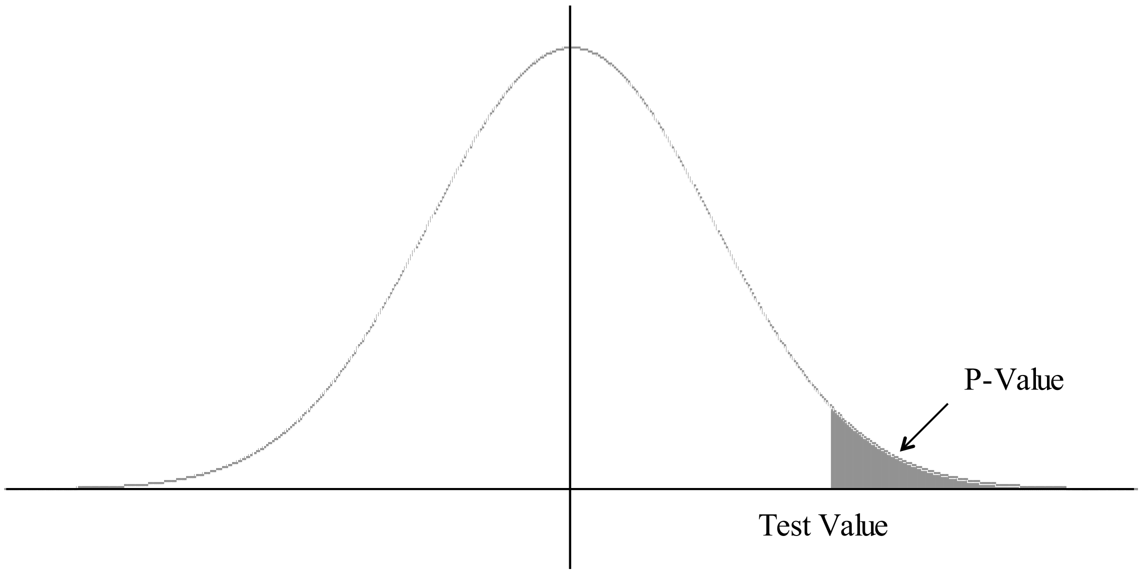

Hypothesis Testing

- In this section, the traditional method for solving hypothesis-testing problems compares ***z*-values**:
  - critical value
  - test value

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Hypothesis Testing

- In this section, the traditional method for solving hypothesis-testing problems compares ***z*-values**:
  - critical value
  - test value
- The *P*-value method for solving hypothesis-testing problems compares **areas**:
  - alpha
  - *P*-value

Procedure Table

Solving Hypothesis-Testing Problems
(*P*-Value Method)

Step 1 State the hypotheses and identify the claim.

Step 2 Compute the test value.

Step 3 Find the *P*-value.

Step 4 Make the decision.

Step 5 Summarize the results.

Chapter 8
Hypothesis Testing

Section 8-2

Example 8-6

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Example 8-6: Cost of College Tuition

A researcher wishes to test the claim that the average cost of tuition and fees at a four-year public college is greater than \$5700. She selects a random sample of 36 four-year public colleges and finds the mean to be \$5950. The population standard deviation is \$659. Is there evidence to support the claim at a 0.05? Use the *P*-value method.

Example 8-6: Cost of College Tuition

A researcher wishes to test the claim that the average cost of tuition and fees at a four-year public college is greater than \$5700. She selects a random sample of 36 four-year public colleges and finds the mean to be \$5950. The population standard deviation is \$659. Is there evidence to support the claim at a 0.05? Use the *P*-value method.

Step 1: State the hypotheses and identify the claim.

H_0: μ = \$5700 and H_1: μ > \$5700 (claim)

Example 8-6: Cost of College Tuition

A researcher wishes to test the claim that the average cost of tuition and fees at a four-year public college is greater than $5700. She selects a random sample of 36 four-year public colleges and finds the mean to be $5950. The population standard deviation is $659. Is there evidence to support the claim at a 0.05? Use the P-value method.

Step 2: Compute the test value.

Example 8-6: Cost of College Tuition

A researcher wishes to test the claim that the average cost of tuition and fees at a four-year public college is greater than $5700. She selects a random sample of 36 four-year public colleges and finds the mean to be $5950. The population standard deviation is $659. Is there evidence to support the claim at a 0.05? Use the P-value method.

Step 2: Compute the test value.

$$z = \frac{\overline{X} - \mu}{\sigma / \sqrt{n}}$$

Example 8-6: Cost of College Tuition

A researcher wishes to test the claim that the average cost of tuition and fees at a four-year public college is greater than $5700. She selects a random sample of 36 four-year public colleges and finds the mean to be $5950. The population standard deviation is $659. Is there evidence to support the claim at a 0.05? Use the P-value method.

Step 2: Compute the test value.

$$z = \frac{\bar{X} - \mu}{\sigma / \sqrt{n}} = \frac{5950 - 5700}{659 / \sqrt{36}}$$

Example 8-6: Cost of College Tuition

A researcher wishes to test the claim that the average cost of tuition and fees at a four-year public college is greater than \$5700. She selects a random sample of 36 four-year public colleges and finds the mean to be \$5950. The population standard deviation is \$659. Is there evidence to support the claim at a 0.05? Use the P-value method.

Step 2: Compute the test value.

$$z = \frac{\bar{X} - \mu}{\sigma / \sqrt{n}} = \frac{5950 - 5700}{659 / \sqrt{36}} = 2.28$$

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Step 3: Find the *P*-value.

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Using Table E, find the area for z = 2.28.

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The area is 0.9887.

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Subtract from 1.0000 to find the area of the tail.

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The area is 0.9887.

Subtract from 1.0000 to find the area of the tail.

Hence, the *P*-value is 1.0000 – 0.9887 = 0.0113.

Example 8-6: Cost of College Tuition

Step 4: Make the decision.

Since the *P*-value is less than 0.05, the decision is to reject the null hypothesis.

Step 5: Summarize the results.

There is enough evidence to support the claim that the tuition and fees at four-year public colleges are greater than $5700.

Note: If α = 0.01, the null hypothesis would not be rejected.

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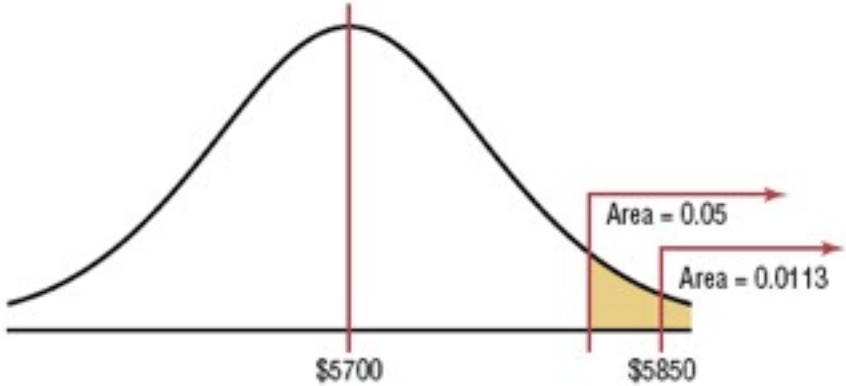

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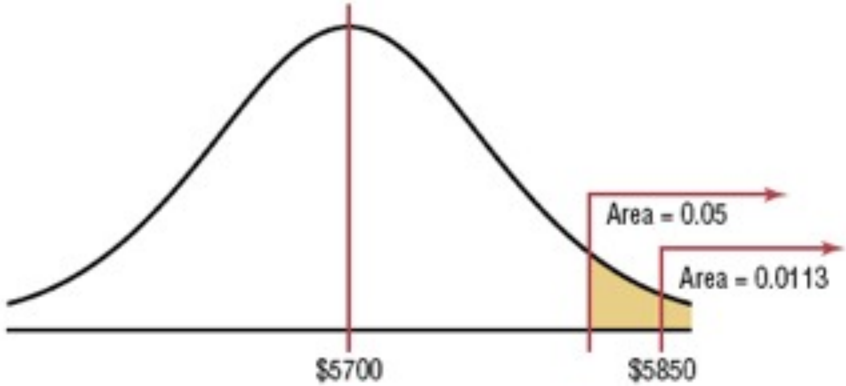

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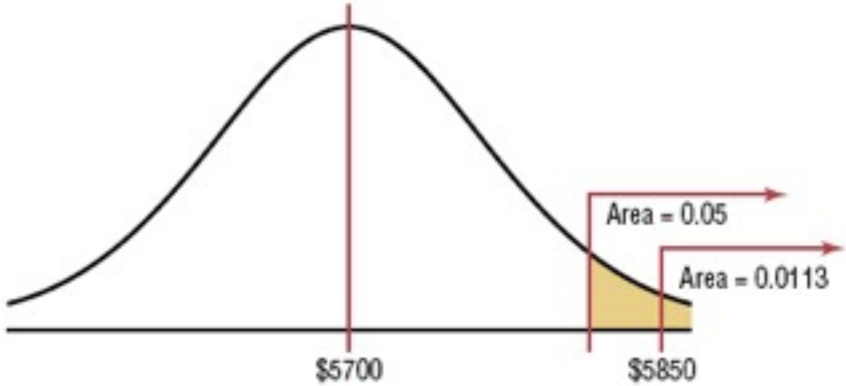

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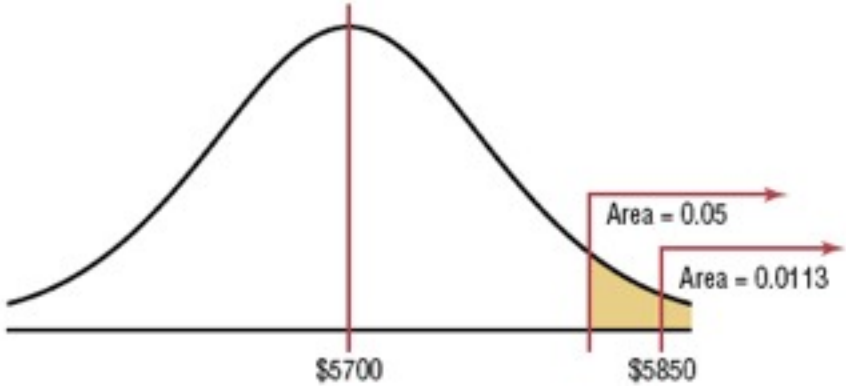

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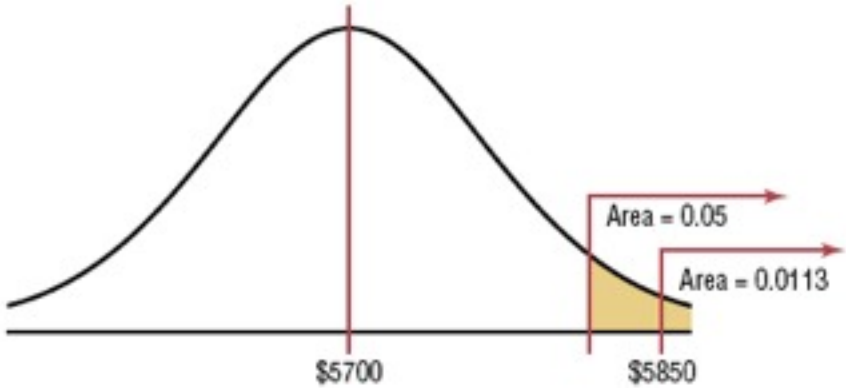

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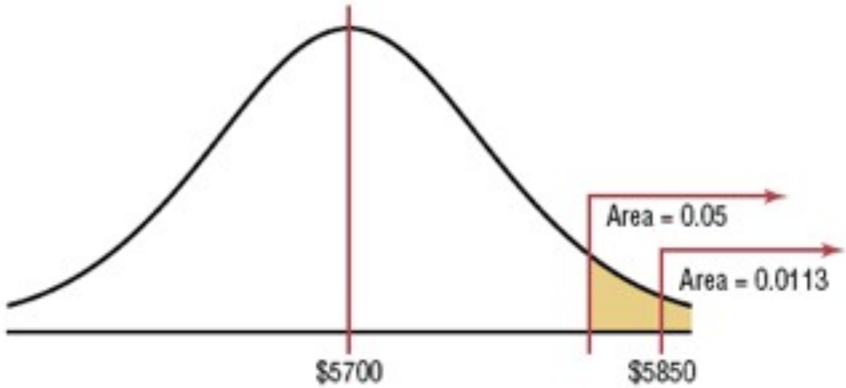

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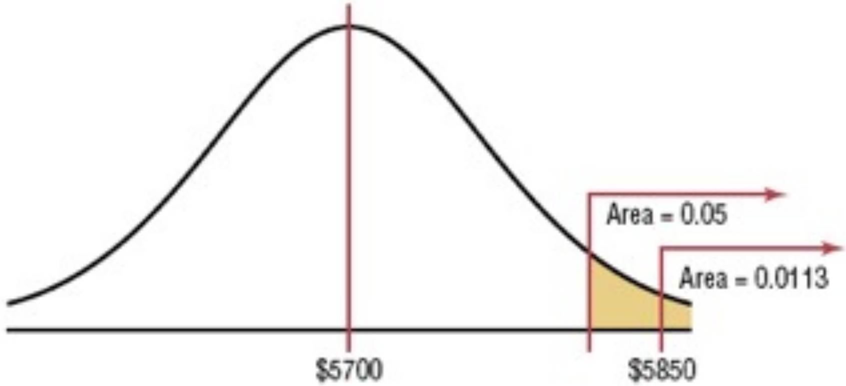

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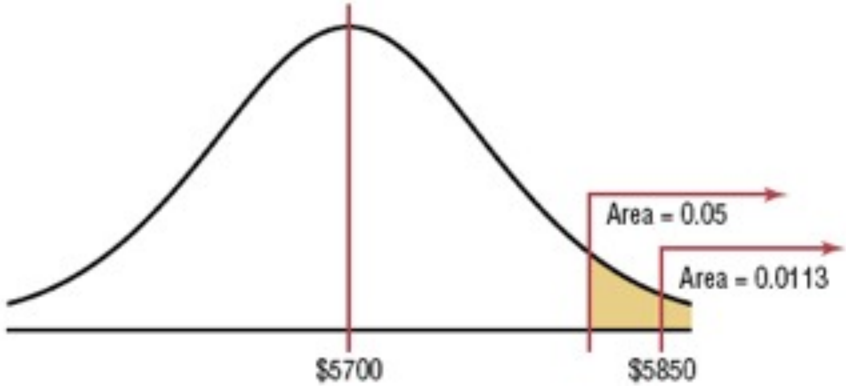

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There is enough evidence to support the claim that the tuition and fees at four-year public colleges are greater than $5700.

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Chapter 8
Hypothesis Testing

Section 8-2

Example 8-7

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Example 8-7: Wind Speed

A researcher claims that the average wind speed in a certain city is 8 miles per hour. A sample of 32 days has an average wind speed of 8.2 miles per hour. The standard deviation of the population is 0.6 mile per hour. At α = 0.05, is there enough evidence to reject the claim? Use the *P*-value method.

Example 8-7: Wind Speed

A researcher claims that the average wind speed in a certain city is 8 miles per hour. A sample of 32 days has an average wind speed of 8.2 miles per hour. The standard deviation of the population is 0.6 mile per hour. At α = 0.05, is there enough evidence to reject the claim? Use the *P*-value method.

Step 1: State the hypotheses and identify the claim.

H_0: $\mu = 8$ (claim) and H_1: $\mu > 8$

Step 2: Compute the test value.

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$$z = \frac{\bar{X} - \mu}{\sigma / \sqrt{n}} = \frac{8.2 - 8}{0.6 / \sqrt{32}}$$

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$$z = \frac{\bar{X} - \mu}{\sigma / \sqrt{n}} = \frac{8.2 - 8}{0.6 / \sqrt{32}} = 1.89$$

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The area for z = 1.89 is 0.9706.

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The area for $z = 1.89$ is 0.9706.

Subtract: 1.0000 – 0.9706 = 0.0294.

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Step 3: Find the *P*-value.

The area for $z = 1.89$ is 0.9706.

Subtract: 1.0000 – 0.9706 = 0.0294.

Since this is a two-tailed test, the area of 0.0294 must be doubled to get the *P*-value.

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Subtract: 1.0000 – 0.9706 = 0.0294.

Since this is a two-tailed test, the area of 0.0294 must be doubled to get the *P*-value.

The *P*-value is 2(0.0294) = 0.0588.

Example 8-7: Wind Speed

Step 4: Make the decision.

The decision is to not reject the null hypothesis, since the *P*-value is greater than 0.05.

Step 5: Summarize the results.

There is not enough evidence to reject the claim that the average wind speed is 8 miles per hour.

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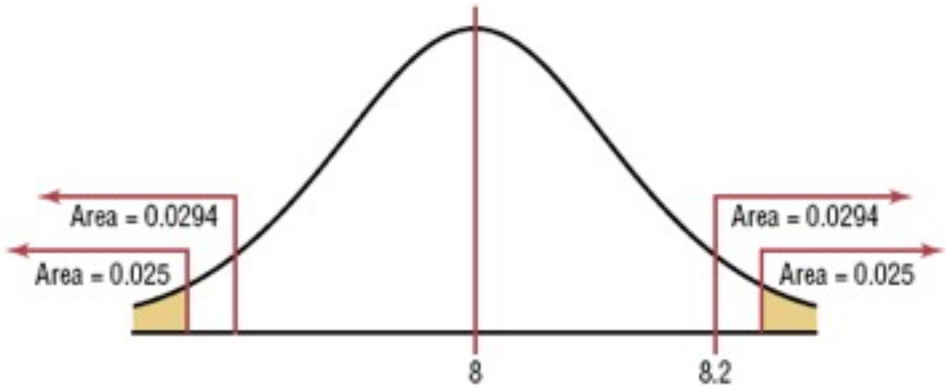

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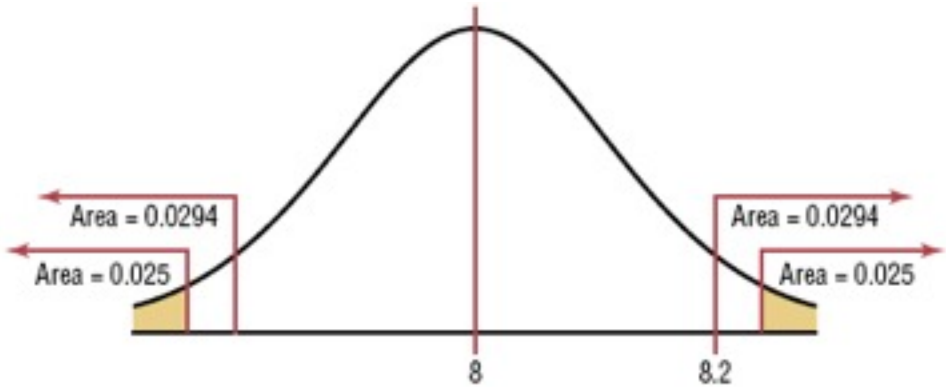

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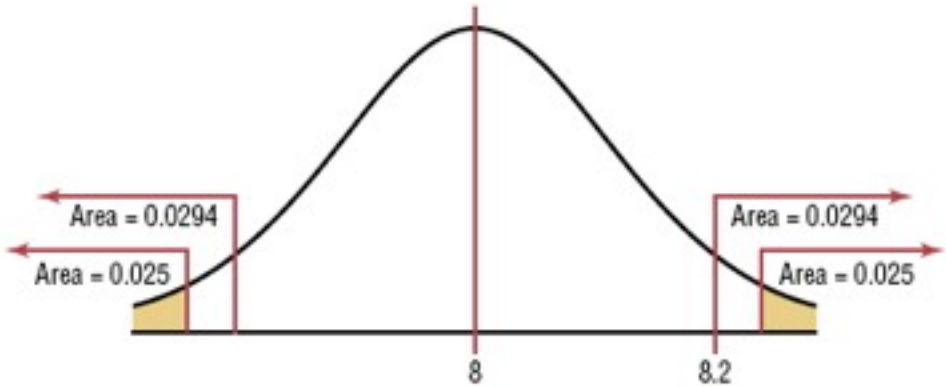

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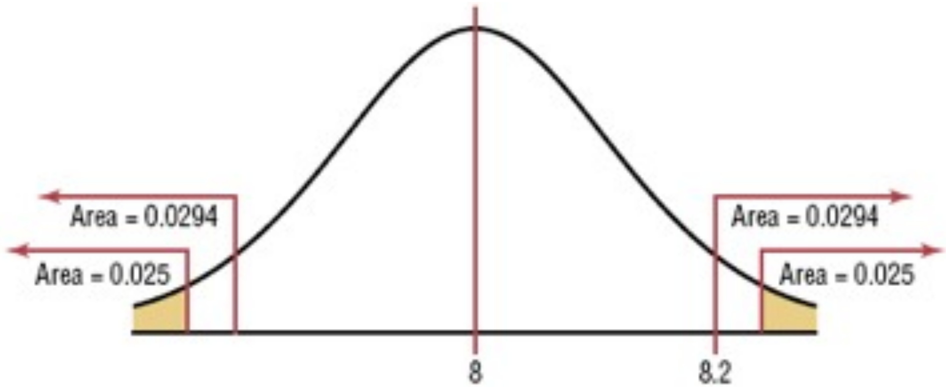

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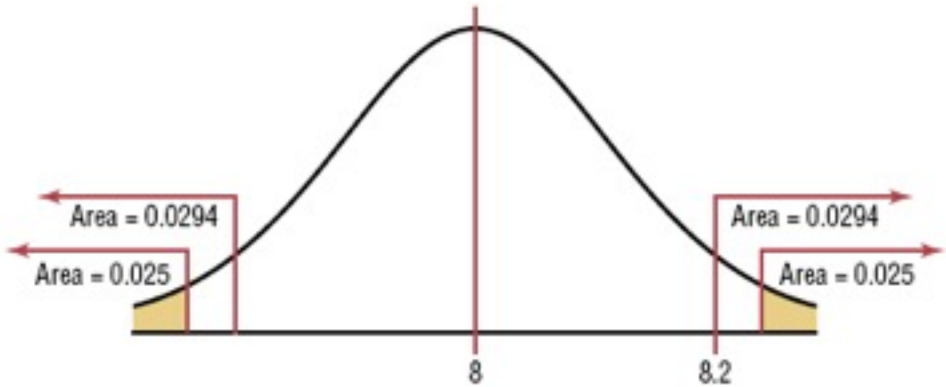

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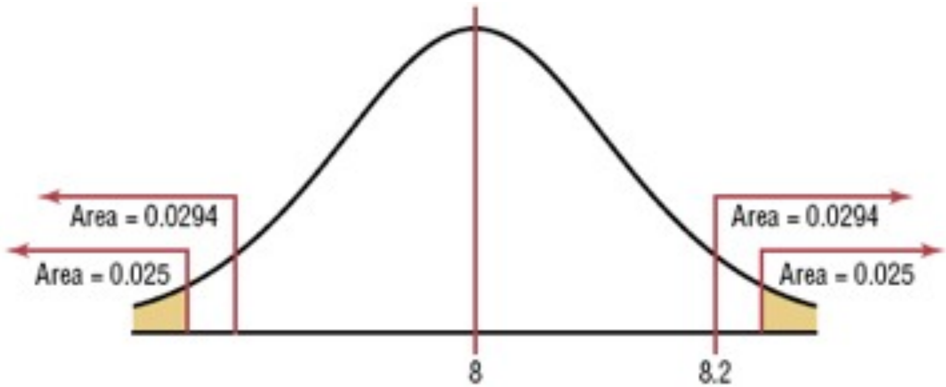

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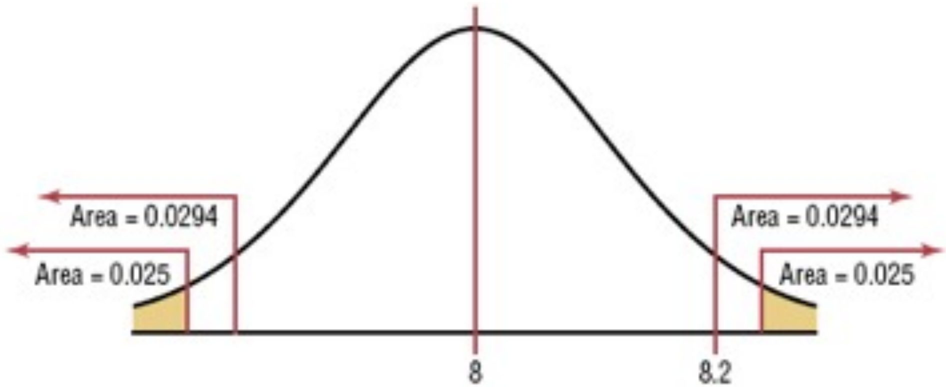

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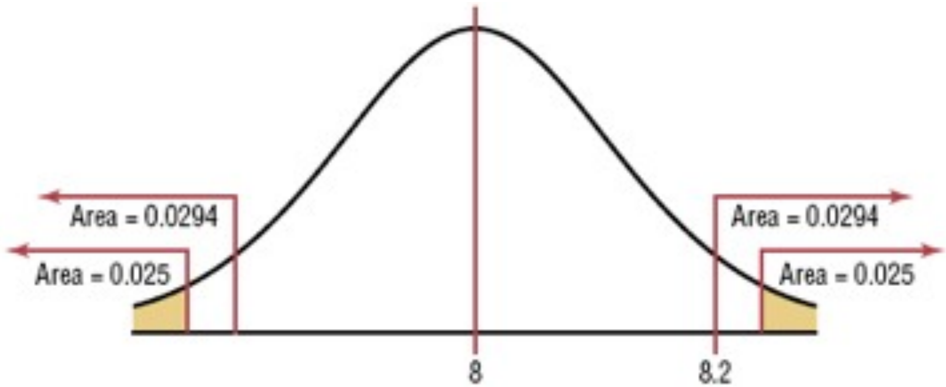

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- If P-value > 0.05 but P-value ≤ 0.10, consider the consequences of type I error before rejecting the null hypothesis.
- If P-value > 0.10, do not reject the null hypothesis. The difference is not significant.

Significance

- The researcher should distinguish between **statistical significance** and **practical significance**.

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- It is up to the researcher to use common sense when interpreting the results of a statistical test.