

# AP<sup>®</sup> STATISTICS

## 2015 SCORING GUIDELINES

### Question 4

#### **Intent of Question**

The primary goal of this question was to assess a student's ability to identify, set up, perform, and interpret the results of an appropriate hypothesis test to address a particular question. More specific goals were to assess a student's ability to (1) state appropriate hypotheses; (2) identify the appropriate statistical test procedure and check appropriate conditions for inference; (3) calculate the appropriate test statistic and  $p$ -value; and (4) draw an appropriate conclusion, with justification, in the context of the study.

#### **Solution**

Step 1: States a correct pair of hypotheses.

Let  $p_{\text{asp}}$  represent the population proportion of adults similar to those in the study who would have developed colon cancer within the six years of the study if they had taken a low-dose aspirin each day. Similarly, let  $p_{\text{plac}}$  represent the population proportion of adults similar to those in the study who would have developed colon cancer within the six years of the study if they had taken a placebo each day.

The hypotheses to be tested are  $H_0 : p_{\text{asp}} = p_{\text{plac}}$  versus  $H_a : p_{\text{asp}} < p_{\text{plac}}$  or equivalently,  
 $H_0 : p_{\text{asp}} - p_{\text{plac}} = 0$  versus  $H_a : p_{\text{asp}} - p_{\text{plac}} < 0$ .

Step 2: Identifies a correct test procedure (by name or by formula) and checks appropriate conditions.

The appropriate procedure is a two-sample  $z$ -test for comparing proportions.

Because this is a randomized experiment, the first condition is that the volunteers were randomly assigned to one treatment group or the other. The condition is satisfied because we are told that the volunteers were randomly assigned to take a low-dose aspirin or a placebo.

The second condition is that the sample sizes are large, relative to the proportions involved. The condition is satisfied because all sample counts are large enough; that is, 15 with colon cancer in aspirin group, 26 with colon cancer in placebo group,  $500 - 15 = 485$  cancer-free in aspirin group, and  $500 - 26 = 474$  cancer-free in placebo group.

Step 3: Calculates the appropriate test statistic and  $p$ -value.

The sample proportions who developed colon cancer are  $\hat{p}_{\text{asp}} = \frac{15}{500} = 0.030$  and  $\hat{p}_{\text{plac}} = \frac{26}{500} = 0.052$ .

The combined sample proportion who developed colon cancer is  $\hat{p}_{\text{combined}} = \frac{15 + 26}{500 + 500} = 0.041$ .

The test statistic is  $z = \frac{0.030 - 0.052}{\sqrt{0.041(1 - 0.041)\left(\frac{1}{500} + \frac{1}{500}\right)}} \approx -1.75$  ( $-1.7542$  from calculator).

The  $p$ -value is  $P(Z \leq -1.75) = 0.0401$  ( $0.0397$  from calculator), where  $Z$  has a standard normal distribution.

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### Question 4 (continued)

Step 4: States a correct conclusion in the context of the study, using the result of the statistical test.

Because the  $p$ -value is less than the given significance level of  $\alpha = 0.05$ , we reject the null hypothesis. The data provide convincing statistical evidence that the proportion of all adults similar to the volunteers who would develop colon cancer if they had taken a low-dose aspirin every day is less than the proportion of all adults similar to the volunteers who would develop colon cancer if they had not taken a low-dose aspirin every day.

### **Scoring**

Steps 1, 2, 3, and 4 are scored as essentially correct (E), partially correct (P), or incorrect (I).

**Step 1** is scored as follows:

Essentially correct (E) if the response identifies correct parameters *AND* both hypotheses are labeled and state the correct relationship between the parameters.

Partially correct (P) if the response identifies correct parameters *OR* states correct relationships, but not both.

Incorrect (I) if the response does not meet the criteria for E or P.

*Note:* Either defining the parameters in context, or simply using common parameter notation with subscripts clearly relevant to the context, such as  $p_{\text{asp}}$  and  $p_{\text{plac}}$ , is sufficient.

**Step 2** is scored as follows:

Essentially correct (E) if the response correctly includes the following three components:

1. Identifies the correct test procedure (by name or by formula).
2. Notes that the use of random assignment satisfies the randomness condition.
3. Checks for approximate normality of the test statistic by citing that all four counts are larger than some standard criterion such as 5 or 10.

Partially correct (P) if the response correctly includes only two of the three components.

Incorrect (I) if the response correctly includes at most one of the three components.

*Notes:*

- For the randomness component, it is (minimally) acceptable to say “random assignment — check” but not acceptable to say “random — check” or “SRS — check.” The important concept here is that it is random assignment, and not random sampling, that is required. If the response implies that the study used a random sample, the randomness component is not satisfied, regardless of whether random assignment is correctly addressed.
- The normality check may use the expected counts under the null hypothesis in place of observed counts.

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**Question 4 (continued)**

**Step 3** is scored as follows:

Essentially correct (E) if the response correctly calculates both the test statistic and a  $p$ -value that is consistent with the stated alternative hypothesis.

Partially correct (P) if the response correctly calculates the test statistic but not the  $p$ -value;

*OR*

if the response calculates the test statistic incorrectly but then calculates the correct  $p$ -value for the computed test statistic;

*OR*

if the response reports the correct  $p$ -value but no calculations or test statistic are shown.

Incorrect (I) if the response fails to meet the criteria for E or P.

*Note:* The  $p$ -value is considered correct if it is consistent with the alternative stated in the response and the calculated test statistic, even if those are incorrect.

**Step 4** is scored as follows:

Essentially correct (E) if the response provides a correct conclusion in context, with justification based on linkage between the  $p$ -value and the given  $\alpha = 0.05$ .

Partially correct (P) if the response provides a correct conclusion, with linkage to the  $p$ -value, but not in context;

*OR*

if the response provides a correct conclusion in context, but without justification based on linkage to the  $p$ -value.

Incorrect (I) if the response does not meet the criteria for E or P.

*Notes:*

- The conclusion must be related to the alternative hypothesis.
- If the  $p$ -value is incorrect, then step 4 is scored as E if the response includes proper linkage and a conclusion in context consistent with that  $p$ -value.
- If the  $p$ -value is less than 0.05, wording that states or implies that the alternative hypothesis is *proven* lowers the score one level (that is, from E to P or P to I) in step 4.
- If the  $p$ -value is incorrect and greater than 0.05, wording that states or implies that the null hypothesis is *accepted* lowers the score one level (that is, from E to P or P to I) in step 4.

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**Question 4 (continued)**

Each essentially correct (E) step counts as 1 point. Each partially correct (P) step counts as  $\frac{1}{2}$  point.

- 4 Complete Response**
- 3 Substantial Response**
- 2 Developing Response**
- 1 Minimal Response**

If a response is between two scores (for example,  $2\frac{1}{2}$  points), use a holistic approach to decide whether to score up or down, depending on the overall strength of the response and communication.