**Lab 10 – Hypothesis Testing**

**To submit: answers to all numbered questions. When the question asks you to write code or create graphs, submit the code and/or graphs in the Word document as part of your answer. Also submit a single .R file that contains all of your code.**

Last week, we used the **t.test** command to construct confidence intervals for means. For example, here we used the **t.test** function in R on thirty randomly-selected net race times from the **TenMileRace** dataset to construct confidence intervals in a single line:

> t.test(racetimes30)

One Sample t-test

data: racetimes30

t = 35.126, df = 29, p-value < 2.2e-16

alternative hypothesis: true mean is not equal to 0

95 percent confidence interval:

5194.265 5836.535

sample estimates:

mean of x

5515.4

Now let’s perform some hypothesis tests by making use of the rest of the output returned by the **t.test** command:

> t.test(survey$Age)

One Sample t-test

data: survey$Age

t = 48.447, df = 236, p-value < 2.2e-16

alternative hypothesis: true mean is not equal to 0

95 percent confidence interval:

19.54600 21.20303

sample estimates:

mean of x

20.37451

We see some familiar variables and labels, from hypothesis tests: df, the number of degrees of freedom, p-value, t (which is ttest from hypothesis tests), and a mention of the alternative hypothesis. Notice that the alternative hypothesis here is that the true mean age is not equal to zero – which is pretty obvious for our data set! Let’s give it a more reasonable null hypothesis: say, that the mean student age is 20.

> t.test(survey$Age, mu=20)

One Sample t-test

data: survey$Age

t = 0.89053, df = 236, p-value = 0.3741

alternative hypothesis: true mean is not equal to 20

95 percent confidence interval:

19.54600 21.20303

sample estimates:

mean of x

20.37451

That’s more like it. We are telling R to test the claim that the mean student age is equal to 20. This is the null hypothesis here. Note that the confidence interval is 0.95, which indicates a default significance of α=0.05.

1. Based on the output of the **t.test** command above, do we reject the null hypothesis? Explain how you used the output of the **t.test** function to make your decision. Write the sentence conclusion that you would write at the end of a hypothesis test that returned the above output, and briefly explain how you arrived at your conclusion
2. Write a function that reads in a list of data, significance level, a claimed value of the mean, information about the mean, and the data units. Your function should perform a hypothesis test and return a sentence conclusion. Sample output:

> hypothesistest(survey$Age, 0.1, 21, "student age", "years")

At alpha= 0.1 , we do not have sufficient evidence to conclude that the mean student age differs from 21 years .

> hypothesistest(survey$Age, 0.2, 21, "student age", "years")

At alpha= 0.2 , we have sufficient evidence to conclude that the mean student age is not 21 years .

We can also do one-sided hypothesis tests using the optional **alternative** argument.

> t.test(survey$Age, mu=19, alternative="greater")

One Sample t-test

data: survey$Age

t = 3.2683, df = 236, p-value = 0.0006215

alternative hypothesis: true mean is greater than 19

95 percent confidence interval:

19.68004 Inf

sample estimates:

mean of x

20.37451

1. At the default significance level of α=0.05, do we have evidence that the mean student age is greater than 19?

Note that the upper bound of the confidence interval is “Inf”, for “infinity”. This is a *one-sided confidence interval*, which we did not cover in class. The **alternative=“greater”** argument tells R that for both the hypothesis test and the confidence interval, we only care about whether the mean student age is greater than 19. R tells is that we are 95% sure that the mean student age is 19.68004 years or older.

We can also make claims about how one mean relates to another. Consider, for instance, the claim that male students are taller on average than female students.

1. Read the help file for **t.test** and then give a sequence of commands to test the claim at α=0.05 that male students are on average taller than female students. Write a sentence stating your conclusion. (You do not have to write a script to do this.) Hint: you need to call **t.test** with three arguments; you can use default values for the rest.
2. Use the **t.test** command to test the claim at α=0.05 that the span of students’ writing hands differs from the span of their non-writing hands. Again you will need to call the **t.test** command with just three arguments, but this is slightly different from the last question. When we compared male and female heights, we selected the male and female students independently of one another. But the hand spans are not independent of each other, because each student (well…the vast majority anyway) has a writing hand and a non-writing hand. Read the help file and experiment if necessary to see how to handle this kind of data. The output is below for you to compare.

data: survey$Wr.Hnd and survey$NW.Hnd

t = 2.1268, df = 235, p-value = 0.03448

alternative hypothesis: true difference in means is not equal to 0

95 percent confidence interval:

0.006367389 0.166513967

sample estimates:

mean of the differences

0.08644068

The next three questions refer to the data in the lab9\_data Excel file.

1. A sample of 5 Boeing 747 aircraft is selected and the times (in hours) required to test each for structural stress fractures are given on the sheet lab9\_Q6.
   1. Since this is a small sample, check that it appears to come from a normally-distributed population
   2. Use your **confidence** function to find a 90% confidence interval for the mean testing time.
   3. Determine at α = 0.10 whether the true mean testing time is 8h.
2. The data in the sheet lab10\_Q7 were obtained in an experiment designed to check whether there is a systematic difference in the weights obtained with two different scales. At α = 0.05 determine whether the mean difference of the weights obtained with the scales is zero.
3. Pull strength tests on 10 soldered leads for a semiconductor device yield the results given in column A of lab10\_Q8, measured in pounds-force required to rupture the bond:

Another set of 8 leads was tested after encapsulation to determine whether the pull strength has been increased by the encapsulation of the device, with the results given in column B of lab10\_Q8.

Test the claim that the mean pull strength after encapsulation is greater than the mean pull strength before encapsulation. α = 0.01.