

CSC100/CSC200 Lab #10: More Hypothesis Testing

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Fall 2022 | Data Science for the World

Please complete this notebook by filling in the cells provided. When you're done:

1. Remember to put your name in the header at the top of this notebook where it says author.
2. Select Knit (Knit to Word) from the toolbar menu.
3. Read that file! If any of your lines are too long and get cut off, we won't be able to see them, so break them up into multiple lines and knit again.
4. Save that Word document as a PDF file.
5. Submit BOTH this .Rmd file and the **PDF** file you generated to Gradescope. Some questions are autograded and you may improve your score on the tests given by resubmitting your work as many times as you like up to the deadline.
6. **Passing the automatic tests given does not guarantee full credit on any question.** The tests are provided to help catch some common mistakes, but it is *your* responsibility to answer the questions correctly.

If you are having trouble submitting, ask your lab instructor for help.

This lab assignment is due **November 7 at 9:00AM**.

Reading:

- Chapter 8 textbook
- Jared Wilber's [permutation test tutorial](#)

Run the cell below to prepare the notebook.

The “Deflategate” scandal

“Deflategate” refers to a scandal about the NFL team New England Patriots using deliberately deflated balls in its 2014-2015 American Football Conference Championship against the Indianapolis Colts. The game took place on January 18, 2015 and the Patriots beat the Colts by 45 - 7. In any National Football League's game, each team prepares a dozen balls to use in their offensive plays. The league dictates that each ball must be inflated so it has air pressure between 12.5 and 13.5 psi (pounds force per square inch). A deflated ball is easier to grab, throw, and catch, and so using a deflated ball gives an advantage to the offensive team.

Prior to the start of the game, the game officials examined the pressure of the balls to find that all the Patriots balls are at around 12.5 psi and the Colts balls are at around 13.0 psi. During the second quarter, a ball thrown by Tom Brady, the then-quarterback of the

Patriots, was intercepted by the Colts. The Colts inspected the ball pressure and found it to be below the minimum 12.5 psi and alerted the game officials.

During the half time, two officials Blakeman and Prioleau checked the pressure of the remaining 11 Patriots balls and 4 Colts balls. They did not have time to check the remaining 8 Colts balls. The results of the inspection are given in `deflategate`.

```
deflategate <- read_csv("data/deflategate.csv")

## Rows: 15 Columns: 3
## — Column specification
## Delimiter: ","
## chr (1): Team
## dbl (2): Blakeman, Prioleau
##
## i Use `spec()` to retrieve the full column specification for this data.
## i Specify the column types or set `show_col_types = FALSE` to quiet this
message.

deflategate

## # A tibble: 15 × 3
##   Team      Blakeman Prioleau
##   <chr>      <dbl>    <dbl>
## 1 Patriots    11.5     11.8
## 2 Patriots    10.8     11.2
## 3 Patriots    11.2     11.5
## 4 Patriots    10.7      11
## 5 Patriots    11.1     11.4
## 6 Patriots    11.6     12.0
## 7 Patriots    11.8     12.3
## 8 Patriots    11.1     11.6
## 9 Patriots    11.0     11.4
## 10 Patriots    10.5     10.9
## 11 Patriots    10.9     11.4
## 12 Colts      12.7     12.4
## 13 Colts      12.8     12.3
## 14 Colts      12.5     13.0
## 15 Colts      12.6     12.2
```

In this lab, we will perform our own analysis of the data using a hypothesis testing technique that we saw during lecture: the *permutation test*.

Part I: The problem. Let's explore the data a bit to see whether the Patriots' drops were indeed larger than the Colts'.

Question 1. Add three new columns to `deflategate` as follows:

- A column `average`, which is the average between `Blakeman` and `Prioleau`.

- A column `pregame`, which is 12.5 for the first 11 rows and 13.0 for the rest. The column represents the pressure of the balls at the start of the game. You can create a vector in which a value `X` repeats `Y` times by `rep(X,Y)` and you can join two vectors using `c()`.
- A column `pressure_drop`, which is `pregame - average`.

Store the resulting tibble in the name `deflategate_with_drop`.

```
deflategate_with_drop <- deflategate %>%
  mutate(average = (Blakeman+Prioleau)/2) %>%
  mutate(pregame = c(rep(12.5,11), rep(13,4))) %>%
  mutate(pressure_drop = pregame-average)
deflategate_with_drop
```

```
## # A tibble: 15 × 6
##   Team      Blakeman Prioleau average pregame pressure_drop
##   <chr>      <dbl>    <dbl>    <dbl>   <dbl>         <dbl>
## 1 Patriots    11.5     11.8     11.6    12.5          0.85
## 2 Patriots    10.8     11.2     11.0    12.5          1.48
## 3 Patriots    11.2     11.5     11.3    12.5          1.18
## 4 Patriots    10.7     11      10.8    12.5          1.65
## 5 Patriots    11.1     11.4     11.3    12.5          1.23
## 6 Patriots    11.6     12.0     11.8    12.5          0.725
## 7 Patriots    11.8     12.3     12.1    12.5          0.425
## 8 Patriots    11.1     11.6     11.3    12.5          1.18
## 9 Patriots    11.0     11.4     11.1    12.5          1.35
## 10 Patriots   10.5     10.9     10.7    12.5          1.8
## 11 Patriots   10.9     11.4     11.1    12.5          1.38
## 12 Colts      12.7     12.4     12.5    13            0.475
## 13 Colts      12.8     12.3     12.5    13            0.475
## 14 Colts      12.5     13.0     12.7    13            0.275
## 15 Colts      12.6     12.2     12.4    13            0.650
```

```
. = ottr::check("tests/deflate_p1_q1.R")
## All tests passed!
```

It looks as though the Patriots' drops were larger than the Colts'. Let's look at the average drop in each of the two groups.

Question 2. Summarize the `deflategate_with_drop` by computing the mean pressure drop in each of the two teams. The resulting tibble should have two columns: `Team` and `pressure_drop_average`. Name this tibble `summarized_average_drops`.

```
summarized_average_drops <- deflategate_with_drop %>%
  group_by(Team) %>%
  summarize(pressure_drop_average = mean(pressure_drop))
summarized_average_drops
```

```
## # A tibble: 2 × 2
##   Team      pressure_drop_average
```

```
##      <chr>                <dbl>
## 1 Colts                 0.469
## 2 Patriots              1.20

. = ottr::check("tests/deflate_p1_q2.R")

## All tests passed!
```

The question now is why the Patriots' footballs had a larger drop in pressure, on average, than the Colts footballs. Could it be due to chance?

Part II: Hypothesis testing. How does chance figure in here? We can make a chance model by hypothesizing that the 11 Patriots' drops look like a random sample of 11 out of all the 15 drops, with the Colts' drops being the remaining four. That's a completely specified chance model under which we can simulate data. Therefore, it is the **null hypothesis**.

Question 1. Given this null hypothesis, give a good definition for the alternative hypothesis.

A good alternative hypothesis is to start by finding the difference in the mean of average pressure drop per team. Then we would wanna randomize these results by shuffling the data and then simulating the experiment to reach a conclusion.

As we have seen before, we must also define a test statistic for this experiment. A natural statistic we can use is the difference between the two average drops, which we will compute as "average drop for Patriots - average drop for Colts".

Question 2. Write a function called `difference_of_means` that takes a tibble as its single argument. It then summarizes this tibble by computing the average pressure drop (in `pressure_drop`) for each group (in `Team`). The function returns the difference between the two average drops, as defined just above.

```
difference_of_means <- function(arg) {
  x<- arg%>%
  group_by(Team)%>%
  summarize(pressure_drop_average = mean(pressure_drop))
  return(as.double(x[2,2]-x[1,2]))
}

difference_of_means(deflategate_with_drop) # an example call

## [1] 0.7335227

. = ottr::check("tests/deflate_p2_q2.R")

## All tests passed!
```

We can use your function to compute the observed test statistic, which we will refer to as `observed_test_stat`:

```
observed_test_stat <- difference_of_means(deflategate_with_drop)
observed_test_stat
```

```
## [1] 0.7335227
```

If the null hypothesis were true, then it shouldn't matter which footballs are labeled Patriots and which are labeled Colts. The distributions of the two sets of drops would be the same. Thus, the *permutation test*.

Part III: Permutation testing. We will now run a permutation test. For each permutation, using the same calculation we compute the difference between the average deflation amount as we did in the previous question.

Question 1. Write a function `deflategate_permute_test()` that does the following:

- From `deflategate_with_drop` create a new column that shuffles the values in `pressure_drop` (you can use `sample()`). Overwrite the column `pressure_drop` with the shuffled values. The resulting tibble can be named whatever you like.
- Call the `difference_of_means()` function you wrote on this shuffled tibble.
- Return the difference.

```
deflategate_permute_test<- function(){
  shuffle_tibble<- deflategate_with_drop%>%
    mutate(pressure_drop = sample(pressure_drop))
  deflategate_with_drop%>%
    mutate(pressure_drop = sample(pressure_drop))
  difference_of_means(shuffle_tibble)
}
deflategate_permute_test()
```

```
## [1] 0.1113636
```

```
. = ottr::check("tests/deflate_p3_q1.R")
```

```
## All tests passed!
```

Question 2. Use `replicate()` on the `deflategate_permute_test()` function you wrote to generate 10,000 sample differences. Store the results in a tibble named `differences_tibble` with a single column named `differences` that gives the generated sample differences.

```
differences_tibble <- data.frame(differences =
c(replicate(10000,deflategate_permute_test())))
```

```
differences_tibble
```

```
##      differences
## 1    -0.19545455
## 2    -0.22102273
## 3    -0.33181818
## 4    -0.46818182
## 5     0.04318182
## 6     0.34147727
## 7     0.12840909
```

## 8	0.0005681818
## 9	-0.0590909091
## 10	-0.1102272727
## 11	0.0943181818
## 12	-0.2977272727
## 13	-0.1613636364
## 14	0.1710227273
## 15	-0.1272727273
## 16	0.1710227273
## 17	-0.3914772727
## 18	-0.1784090909
## 19	0.2306818182
## 20	0.2988636364
## 21	0.2732954545
## 22	-0.0420454545
## 23	0.0176136364
## 24	-0.3403409091
## 25	-0.3744318182
## 26	0.0857954545
## 27	-0.0931818182
## 28	-0.0420454545
## 29	0.1028409091
## 30	0.0090909091
## 31	0.2136363636
## 32	-0.3062500000
## 33	0.2051136364
## 34	0.2562500000
## 35	0.0857954545
## 36	0.0431818182
## 37	0.0176136364
## 38	0.2562500000
## 39	0.4948863636
## 40	0.1198863636
## 41	0.1625000000
## 42	-0.0505681818
## 43	-0.0250000000
## 44	-0.0505681818
## 45	-0.2806818182
## 46	0.4948863636
## 47	0.3329545455
## 48	0.0005681818
## 49	0.5034090909
## 50	0.0090909091
## 51	-0.0761363636
## 52	0.0857954545
## 53	0.4948863636
## 54	-0.5278409091
## 55	-0.6045454545
## 56	-0.3829545455
## 57	-0.4937500000

## 58	-0.0420454545
## 59	0.0005681818
## 60	-0.3914772727
## 61	-0.6301136364
## 62	0.2647727273
## 63	0.6142045455
## 64	0.2136363636
## 65	-0.4085227273
## 66	-0.1528409091
## 67	-0.3573863636
## 68	-0.6045454545
## 69	-0.4511363636
## 70	0.3244318182
## 71	-0.4426136364
## 72	0.3500000000
## 73	-0.1528409091
## 74	0.1028409091
## 75	-0.5107954545
## 76	-0.0590909091
## 77	0.2136363636
## 78	0.3500000000
## 79	0.3159090909
## 80	-0.4681818182
## 81	-0.0505681818
## 82	0.2562500000
## 83	-0.3147727273
## 84	-0.3147727273
## 85	0.0005681818
## 86	-0.0420454545
## 87	-0.0931818182
## 88	0.1965909091
## 89	-0.2380681818
## 90	-0.0676136364
## 91	0.2562500000
## 92	0.0346590909
## 93	0.2988636364
## 94	0.2732954545
## 95	0.2392045455
## 96	0.4522727273
## 97	-0.4255681818
## 98	0.0517045455
## 99	-0.1528409091
## 100	-0.5789772727
## 101	-0.3744318182
## 102	0.0176136364
## 103	0.1198863636
## 104	-0.2295454545
## 105	0.0943181818
## 106	-0.1613636364
## 107	0.1539772727

```
## 108 -0.1187500000
## 109 0.2988636364
## 110 0.4437500000
## 111 -0.2039772727
## 112 -0.1528409091
## 113 0.0772727273
## 114 -0.5960227273
## 115 0.0772727273
## 116 0.2306818182
## 117 0.2903409091
## 118 0.3840909091
## 119 -0.1017045455
## 120 0.5715909091
## 121 0.0346590909
## 122 -0.4000000000
## 123 0.1369318182
## 124 0.3329545455
## 125 0.5119318182
## 126 -0.4596590909
## 127 0.2818181818
## 128 0.2562500000
## 129 -0.1102272727
## 130 0.0857954545
## 131 -0.1613636364
## 132 -0.1698863636
## 133 -0.1102272727
## 134 -0.3659090909
## 135 -0.0079545455
## 136 -0.3573863636
## 137 0.1625000000
## 138 0.2392045455
## 139 -0.0761363636
## 140 -0.3147727273
## 141 0.2903409091
## 142 0.2562500000
## 143 0.0857954545
## 144 0.3414772727
## 145 0.0090909091
## 146 -0.0761363636
## 147 0.2988636364
## 148 0.3159090909
## 149 -0.4000000000
## 150 -0.0335227273
## 151 -0.0164772727
## 152 -0.3659090909
## 153 -0.0505681818
## 154 0.4437500000
## 155 -0.2039772727
## 156 -0.1528409091
## 157 -0.3062500000
```


## 158	0.0346590909
## 159	0.5801136364
## 160	-0.1102272727
## 161	0.5119318182
## 162	-0.1017045455
## 163	0.4437500000
## 164	0.2306818182
## 165	0.5545454545
## 166	0.0346590909
## 167	0.4522727273
## 168	-0.2892045455
## 169	-0.3488636364
## 170	-0.2636363636
## 171	0.0090909091
## 172	0.2306818182
## 173	0.1880681818
## 174	-0.0846590909
## 175	-0.3403409091
## 176	0.0857954545
## 177	-0.0250000000
## 178	-0.6301136364
## 179	0.0261363636
## 180	-0.3744318182
## 181	0.0346590909
## 182	0.2306818182
## 183	-0.0590909091
## 184	0.7079545455
## 185	0.0602272727
## 186	-0.2806818182
## 187	0.1880681818
## 188	-0.1954545455
## 189	0.0687500000
## 190	0.1028409091
## 191	0.2988636364
## 192	-0.0250000000
## 193	0.1369318182
## 194	0.1454545455
## 195	-0.0250000000
## 196	-0.3744318182
## 197	-0.2039772727
## 198	0.2988636364
## 199	0.0857954545
## 200	-0.0505681818
## 201	-0.3147727273
## 202	0.0602272727
## 203	0.1625000000
## 204	0.0176136364
## 205	0.0687500000
## 206	0.1965909091
## 207	0.2818181818

## 208	-0.3062500000
## 209	0.0602272727
## 210	0.1284090909
## 211	0.0602272727
## 212	-0.0335227273
## 213	0.2306818182
## 214	0.4778409091
## 215	0.4096590909
## 216	-0.0505681818
## 217	-0.1272727273
## 218	0.0005681818
## 219	-0.0335227273
## 220	-0.2806818182
## 221	0.0005681818
## 222	-0.2977272727
## 223	-0.2465909091
## 224	-0.0761363636
## 225	0.1028409091
## 226	-0.5107954545
## 227	0.7250000000
## 228	-0.1698863636
## 229	0.1880681818
## 230	-0.0420454545
## 231	-0.2210227273
## 232	-0.2039772727
## 233	0.5545454545
## 234	0.4778409091
## 235	-0.1272727273
## 236	-0.1784090909
## 237	0.0005681818
## 238	0.2136363636
## 239	0.3329545455
## 240	-0.2551136364
## 241	0.1113636364
## 242	-0.3147727273
## 243	0.2477272727
## 244	0.1369318182
## 245	-0.0079545455
## 246	0.0687500000
## 247	-0.1613636364
## 248	-0.2636363636
## 249	0.6056818182
## 250	0.3414772727
## 251	0.2988636364
## 252	0.3414772727
## 253	0.1454545455
## 254	-0.3318181818
## 255	0.1028409091
## 256	0.0005681818
## 257	0.1880681818

## 258	0.0005681818
## 259	-0.1017045455
## 260	-0.1613636364
## 261	0.1965909091
## 262	0.2306818182
## 263	-0.0335227273
## 264	-0.1102272727
## 265	0.3159090909
## 266	-0.2380681818
## 267	-0.1357954545
## 268	0.3244318182
## 269	0.0772727273
## 270	-0.2295454545
## 271	0.1539772727
## 272	0.2988636364
## 273	-0.0079545455
## 274	-0.3488636364
## 275	0.4948863636
## 276	-0.6130681818
## 277	0.3500000000
## 278	-0.0420454545
## 279	0.3159090909
## 280	0.4522727273
## 281	-0.2380681818
## 282	0.1198863636
## 283	-0.3232954545
## 284	0.1795454545
## 285	0.0943181818
## 286	-0.3403409091
## 287	-0.2380681818
## 288	-0.0335227273
## 289	0.0346590909
## 290	0.0261363636
## 291	0.0431818182
## 292	-0.1357954545
## 293	-0.4767045455
## 294	0.4011363636
## 295	-0.3147727273
## 296	0.1369318182
## 297	-0.5534090909
## 298	0.2732954545
## 299	0.0857954545
## 300	-0.0164772727
## 301	0.1028409091
## 302	-0.0250000000
## 303	0.1284090909
## 304	0.0176136364
## 305	0.2136363636
## 306	-0.3147727273
## 307	0.3414772727

## 308	0.2392045455
## 309	0.2136363636
## 310	-0.0164772727
## 311	0.0261363636
## 312	0.0857954545
## 313	-0.0505681818
## 314	-0.6045454545
## 315	-0.0931818182
## 316	0.4863636364
## 317	0.2903409091
## 318	0.2562500000
## 319	-0.2380681818
## 320	-0.2551136364
## 321	0.0943181818
## 322	-0.1869318182
## 323	-0.1187500000
## 324	-0.2977272727
## 325	-0.1357954545
## 326	-0.1784090909
## 327	0.0176136364
## 328	-0.1528409091
## 329	-0.1528409091
## 330	0.2732954545
## 331	0.4693181818
## 332	-0.5022727273
## 333	-0.0420454545
## 334	0.4693181818
## 335	-0.0335227273
## 336	-0.2380681818
## 337	-0.5193181818
## 338	0.2562500000
## 339	-0.3232954545
## 340	0.2988636364
## 341	0.5545454545
## 342	0.0005681818
## 343	-0.2977272727
## 344	0.4437500000
## 345	0.2647727273
## 346	-0.2721590909
## 347	-0.2892045455
## 348	0.1539772727
## 349	0.0005681818
## 350	-0.4000000000
## 351	0.1284090909
## 352	-0.0931818182
## 353	0.2306818182
## 354	-0.1272727273
## 355	-0.1017045455
## 356	0.2477272727
## 357	0.0517045455

## 358	0.4096590909
## 359	0.0005681818
## 360	-0.2721590909
## 361	0.3585227273
## 362	0.3329545455
## 363	-0.1613636364
## 364	0.5801136364
## 365	-0.2892045455
## 366	-0.2295454545
## 367	0.2477272727
## 368	-0.0761363636
## 369	0.5545454545
## 370	0.3244318182
## 371	-0.0590909091
## 372	-0.3488636364
## 373	0.3670454545
## 374	0.1369318182
## 375	0.6482954545
## 376	0.1113636364
## 377	0.3755681818
## 378	0.0857954545
## 379	-0.1102272727
## 380	-0.4340909091
## 381	0.1710227273
## 382	-0.1784090909
## 383	0.3585227273
## 384	0.1880681818
## 385	0.1454545455
## 386	0.6482954545
## 387	0.2562500000
## 388	0.0687500000
## 389	0.1710227273
## 390	-0.2977272727
## 391	0.1198863636
## 392	0.1028409091
## 393	0.2306818182
## 394	-0.1272727273
## 395	0.1880681818
## 396	-0.2977272727
## 397	-0.2125000000
## 398	-0.0931818182
## 399	0.5801136364
## 400	-0.2380681818
## 401	-0.6727272727
## 402	0.0090909091
## 403	0.0431818182
## 404	-0.1272727273
## 405	0.1625000000
## 406	-0.2125000000
## 407	-0.3744318182

## 408	0.3585227273
## 409	-0.0505681818
## 410	0.2818181818
## 411	0.3500000000
## 412	-0.0761363636
## 413	0.3500000000
## 414	-0.1102272727
## 415	0.2903409091
## 416	0.6653409091
## 417	0.1795454545
## 418	-0.4000000000
## 419	0.0176136364
## 420	0.2732954545
## 421	0.1028409091
## 422	-0.1102272727
## 423	-0.0676136364
## 424	-0.2977272727
## 425	0.0943181818
## 426	-0.5107954545
## 427	-0.2210227273
## 428	-0.0505681818
## 429	-0.3232954545
## 430	-0.3744318182
## 431	0.0857954545
## 432	0.1795454545
## 433	-0.1102272727
## 434	-0.2380681818
## 435	0.0602272727
## 436	0.5119318182
## 437	0.1625000000
## 438	-0.2977272727
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9930 0.1880681818
9931 -0.0505681818
9932 -0.1954545455
9933 -0.1187500000
9934 -0.0420454545
9935 0.0772727273
9936 0.3670454545
9937 -0.1613636364
9938 -0.2210227273
9939 -0.6642045455
9940 0.0943181818
9941 -0.4340909091
9942 -0.2806818182
9943 0.0857954545
9944 -0.6215909091
9945 -0.2806818182
9946 -0.3659090909
9947 -0.4937500000
9948 0.3414772727
9949 0.1795454545
9950 -0.2806818182
9951 -0.2125000000
9952 0.0176136364
9953 0.5289772727
9954 0.1454545455
9955 -0.3062500000
9956 -0.4255681818
9957 0.1539772727

```
## 9958 -0.2039772727
## 9959 0.3585227273
## 9960 -0.2380681818
## 9961 0.3414772727
## 9962 -0.6642045455
## 9963 -0.0505681818
## 9964 0.1710227273
## 9965 0.1028409091
## 9966 -0.5107954545
## 9967 -0.3147727273
## 9968 -0.2551136364
## 9969 -0.2210227273
## 9970 0.1284090909
## 9971 -0.2465909091
## 9972 -0.1443181818
## 9973 -0.6727272727
## 9974 -0.0761363636
## 9975 -0.5875000000
## 9976 0.3159090909
## 9977 0.0176136364
## 9978 0.5119318182
## 9979 0.1880681818
## 9980 0.1795454545
## 9981 -0.0079545455
## 9982 0.1028409091
## 9983 -0.4511363636
## 9984 0.1198863636
## 9985 -0.2892045455
## 9986 -0.1613636364
## 9987 0.0005681818
## 9988 -0.0931818182
## 9989 -0.0335227273
## 9990 0.1028409091
## 9991 -0.1528409091
## 9992 0.2562500000
## 9993 0.0772727273
## 9994 -0.2721590909
## 9995 0.0431818182
## 9996 -0.0846590909
## 9997 -0.3659090909
## 9998 0.1454545455
## 9999 -0.3744318182
## 10000 -0.1528409091
```

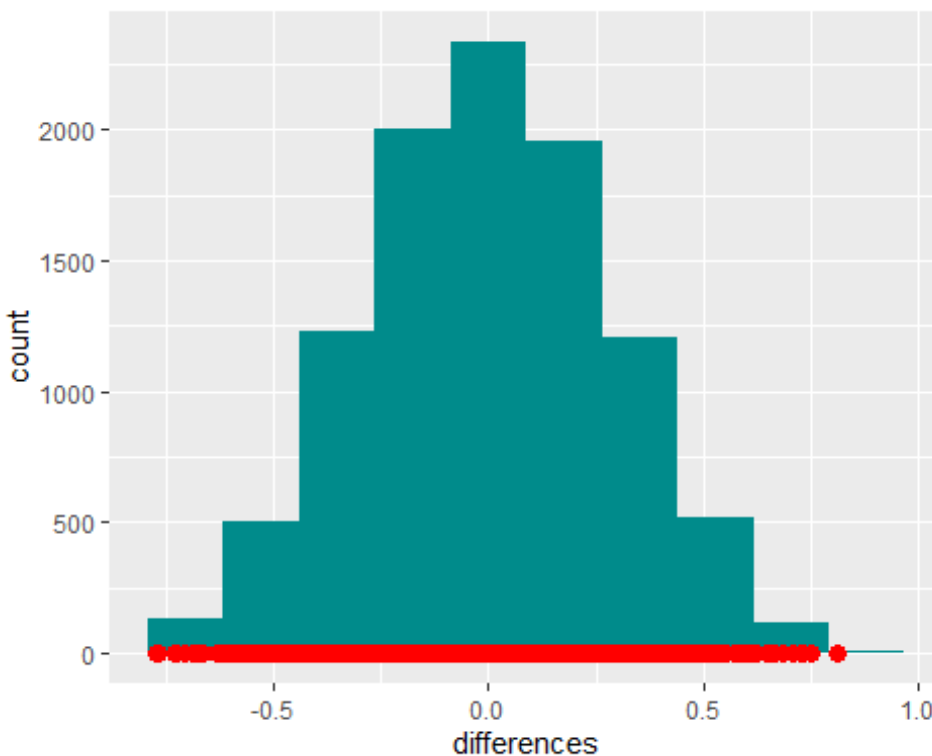
```
. = ottr::check("tests/deflate_p3_q2.R")
```

```
## All tests passed!
```

Part IV: Visualization & Conclusion. Let us unpack the results from our simulation.

Question 1. We are ready to put the data on a histogram. Plot a histogram using ggplot. Use 10 as the number of bins and “darkcyan” as the fill color. Add also the point representing the observed_test_stat using geom_point at $y = 0$ with the color “red” and size 3.

```
ggplot(differences_tibble, aes(x=differences)) +  
  geom_histogram(fill = "darkcyan" , bins = 10) +  
  geom_point(y = 0, color = "red", size = 3)
```



Question 2. The bulk of the distribution is centered around 0. Using what you know about the stated null hypothesis, why should the distribution turn out this way?

The distribution is centered around 0. This shows that the data is fair and that the null hypothesis is indeed true for the data. The distribution should turn out this way because it's a fair distribution.

Where do you see the red point appear relative to the histograms? Is it close or beyond the end of the range of the differences? We can see that the observed difference is an unlikely event.

Question 3. Formalize the observation by computing the p-value.

```
pvalue <- sum(differences_tibble >= observed_test_stat)/10000  
pvalue  
## [1] 0.0024
```

```
. = ottr::check("tests/deflate_p4_q3.R")  
## All tests passed!
```

Question 4. Following are some conclusions that could be drawn based on the p-value you just found. Evaluate each of these statements and explain whether or not the statement is correct.

1. We reject the NH with over 99% confidence.
2. We fail to reject the NH at a significance level of 99%.
3. We accept the NH with over 99% confidence.
4. The p-value obtained is evidence that the observed difference is not due to chance.
5. The p-value obtained is enough evidence to show that the excess drop of pressure in the Patriots' footballs was indeed deliberate.

1. True because the value is less than 0.05% 2. False we reject it. 3. False the NH hovers around 0, but the pvalue shows that the data wasnt near 0. 4. True The lower the pvalue the more evidence you have to reject the NH. We got 0.0026 which is very low. 5. True based on null hypothesis and pvalue.

Further reading

If you are curious about the scandal, you can read more about it [here](#).

Touchdown – you finished Lab #10!