An Analysis of Caffeine's Impact on Physical Performance

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Introduction

The consumption of energy drinks has increased worldwide, specifically among teens and individuals in their twenties. Intrigued by the exclusive marketing towards college students, our group decided to examine the physical effects of caffeine. After a random selection of students in 3 different universities–Arcadia, Hofn, and Colmar–we allocated different levels of caffeine, and recorded the time it takes to complete a 100m run outdoors. Our general expectation for this project is to observe that higher levels of caffeine consumption results in faster running times.

Design

The goal of the study is to investigate the effects of different levels of caffeine on physical performance. Therefore we chose a one factor design as we focused on caffeine alone and did not involve other factors and their interactions. We blocked gender and weight as we believed they may affect the response variable, ensuring any effect on the run time was solely based on the levels of caffeine.

Initially we chose 150 participants from the three universities, and after running the power test, we were able to see that it recommended 120 for the sample size which supports our initial sample size [Figure 1.1]. We also wanted to see how large of a sample size we would need if we wanted to see even smaller discrepancies in running speed. The power analysis suggested using 1036 participants for a 1 second difference [Figure 1.2] and 52500 participants for a 0.14 second difference [Figure 1.3].

Figure 1.1

```
> pwr.anova.test(k = 4, f = 3/sqrt(72.6), power =0.9)

     Balanced one-way analysis of variance power calculation

              k = 4
              n = 29.57626
              f = 0.3520894
      sig.level = 0.05
          power = 0.9

NOTE: n is number in each group
```

Figure 1.2

```
> pwr.anova.test(k = 4, f = 1/sqrt(72

     Balanced one-way analysis of var

              k = 4
              n = 258.1916
              f = 0.1173631
      sig.level = 0.05
          power = 0.9

NOTE: n is number in each group
```

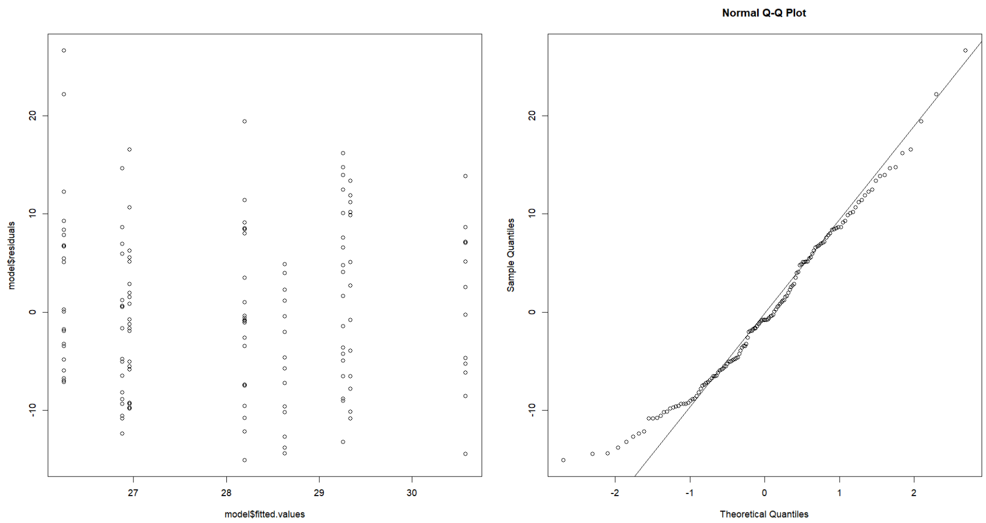
Figure 1.3

```
> pwr.anova.test(k = 4, f = 0.14/sqrt

     Balanced one-way analysis of var

              k = 4
              n = 13124.06
              f = 0.01643084
      sig.level = 0.05
          power = 0.9

NOTE: n is number in each group
```

Results and interpretation

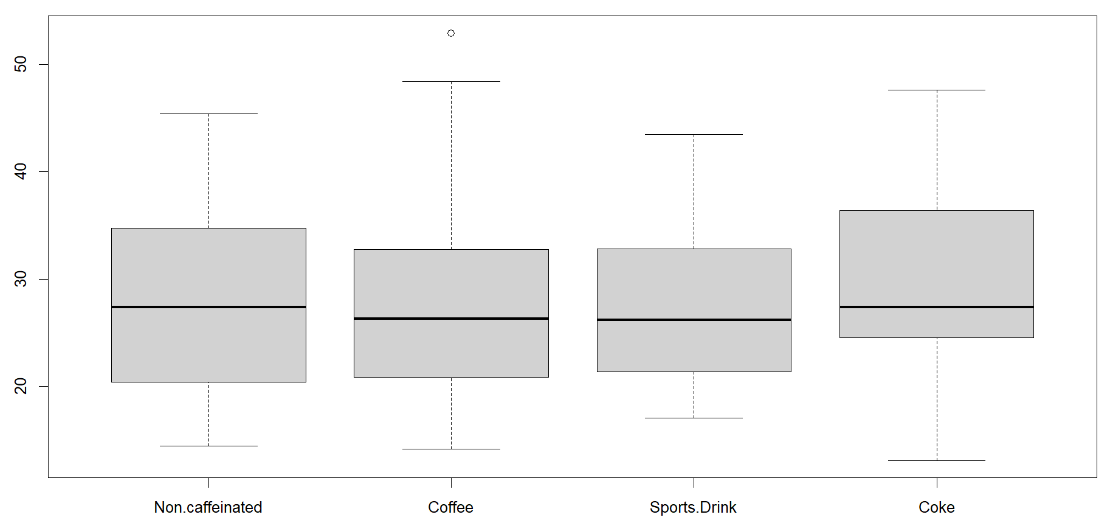
To begin our experiment, we initially want to check the model assumptions from our data set, which we found were mostly satisfied. Our residual plot is scattered and our normal QQ plot is mostly linear with some expected tailing due to our response variable being time.

Figure 2



We also looked at the shape of our different variables, with most of our values looking daily normal, but with coke being particularly right skewed

Figure 3



Additionally, we wanted to determine if blocking would be helpful in our experiment. We wanted to test blocks for gender and for weight as we figured these could potentially be large nuisance factors in our experiment. As seen in Figure 4.1 which shows the ANOVA table with no blocking and Figure 4.2 which shows the ANOVA table with blocking, our probability value decreases by blocking, but does not change that the treatment is not significant. Furthermore, although we can not statistically test for it, we can notice that the mean square of the blocks are much larger than the mean square of the residuals, which indicates that blocking is likely necessary.

Figure 4.1

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
factor(treatment)	3	59	19.75	0.268	0.849
Residuals	136	10038	73.81		

Figure 4.2

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
factor(gender_block)	1	177	177.37	2.491	0.117
factor(weight_block)	3	375	124.91	1.754	0.159
factor(treatment)	3	145	48.28	0.678	0.567
Residuals	132	9400	71.21		

Based on these results, we conclude that there is no significant effect of different levels of caffeine on the run time of a 100m race for university students.

Discussion

Summary

In conclusion, our research aims to explore the impact of varying caffeine intake levels on physical performance. Through the simulated world of "The Islands," we administered four distinct treatments—cola, coffee, sports drink, and a control group without caffeine—on students from three different universities, and recorded their 100m run times. Our analysis yielded an unexpected outcome: contrary to our initial hypothesis, caffeine consumption levels demonstrated no significant influence on participants' performance in the 100m dash.

In the Real World

After thorough research, we found that our results do not make sense in the real world. Caffeine does, in fact, affect a runner's performance in a 100m dash. An experiment conducted by Ritsumeikan University and Nippon Sport Science University found that caffeine can "shorten a 100m runtime by an average of 0.14s" (Matsumura 1). The study discovered that caffeine amplified the runners' velocity in the first 20 m of the sprint, particularly in the early acceleration stage. This is most likely due to the effect of caffeine on your body's muscle activation. The greater the force applied per unit of velocity, the stronger or more "explosive" strength you are considered to have. This measurement is known as the Rate of Force Development and is commonly used to define what makes a "successful" athlete. As far as it is known, this is the first study to evaluate the direct effects of caffeine on the 100m sprint. However, it is important to note that the study had only thirteen participants and distributed the same amount of caffeine or placebo per participant. This differed from our experiment, which had varying amounts of caffeine per drink.

Limitations and Future Improvements

Reflecting on our study, it's crucial to acknowledge the limitations that may have impacted our ability to draw final conclusions applicable to the real world. Firstly, it is necessary to acknowledge that the difference we would have to look for would be extremely small. The 100m dash is very difficult to make a large improvement in time, and improvements we see could be in the tenths of a second. This reflects the real world study we see, and based on our power analysis we can see that the necessary sample size to find those differences statistically significant are absurdly large.

Secondly, the effects of caffeine on physical performance may have been overshadowed by the variability inherent in human physiology, potentially resulting in statistically insignificant results. Moreover, we relied on online sources for the average caffeine content in each drink, introducing uncertainty regarding the exact dosage administered in “The Islands,” and possibly confounding our findings.

Furthermore, individuals’ varying responses to caffeine present a challenge in isolating its impact on athletic performance. While some participants may experience heightened alertness and improved reaction times, others might become more anxious, likely compromising their performance. In addition, our sample size might not have adequately captured these diverse responses. As suggested by the power analysis test, we would need a substantially larger participant pool to achieve the results found in the real-world example that was previously mentioned.

Lastly, looking at our experimental design, while we took weight and gender into consideration as a nuisance factor, it would be reasonable to acknowledge other factors that may have affected the results. For instance, we failed to consider a person's medical condition such as their blood pressure or illnesses. This could have skewed our results, especially since caffeine affects people differently. Another limitation we faced was that our sample was composed of various students of varying athletic experience and ability. In the 100m dash, form and experience is crucial. The real-world study took a look at athletes who were experienced in sprinting who give a consistent baseline. The performance of an inexperienced runner can be inconsistent between runs.

If we were to repeat this experiment and given the proper resources, we would conduct physiological evaluations before and after the caffeine intakes, randomize our sample group, and deliver treatments at a consistent time. By incorporating these improvements, our analysis would yield a result similar to research done in the real world.

Citations

Matsumura T, Tomoo K, Sugimoto T, Tsukamoto H, Shinohara Y, Otsuka M, Hashimoto T. Acute Effect of Caffeine Supplementation on 100-m Sprint Running Performance: A Field Test. Med Sci Sports Exerc. 2023 Mar 1;55(3):525-533. doi: 10.1249/MSS.0000000000003057. Epub 2022 Oct 13. PMID: 36251383; PMCID: PMC9924959.