Determining the Effect of Recreational Drug Use on Athletic Performance

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Abstract – At their very core, athletes too are human, and so as humans, they too tend to indulge in the consumption of drugs such as marijuana and alcohol on a "regular" basis – and at certain times, their over-consumption. In this study, we examine to what effect, if at all, this behavior, specifically during a "night out" with their teammates, has on their performance the following day. We perform this experiment with inhabitants from the Island onto whom we apply different treatments the night before and compare the mean differences in their coordination and performance the next day.

I. INTRODUCTION

Elite levels of sports demand high amounts of competition, commitment and sacrifice to perform at the professional level. These sports organizations require athletes to hold practices, tournaments, team schedules, games and many other responsibilities. As a result, many athletes may turn to drugs and alcohol to deal with the stressors of athletic life and competition in hopes of enhancing performance, treating mental illnesses, and dealing with physical pain or injuries. Such drugs may vary in potency, but may include marijuana and alcohol, two of the most common drugs used by athletes (Reardon). These substances are believed by some sports professionals to reduce anxiety and pain from injuries.

The medical use of marijuana is not a new phenomenon, as pain treatment with cannabis has dated back to 2900 BC. Cannabis, colloquially known as "marijuana" has active cannabinoids, such as THC (tetrahydrocannabinol), CBD (cannabidiol), and CBN (cannabinol), that are hypothesized to inhibit pain as they attach to receptors and ligands that affect the bodies physiological processes with pain and inflammatory response, acting like a sort of acute sedative. As a result, "there is converging evidence to support the notion that marijuana can produce acute pain-inhibitory effects among individuals with chronic pain" (Zeiger). It is only now due to states in the US, allowing legal use of marijuana that it has seen a rise in popularity among individuals, especially athletes who use the drug to treat chronic pain and mental illnesses, or for recreational use.

Even though the use of marijuana is now being accepted by local governments and public opinion is now shifting to acceptance of the drug, it is still a controversial topic in sports today. In recent years however, many professional sports such as the NBA, NFL and MLB are looking into the benefits of marijuana use for pain and anxiety among athletes and are now having conversations about allowing athletes to use marijuana for recreational and medical use, while the NHL have already legalized the use and have no penalties associated with the drug. Many professional athletes have advocated of the use of the drug such as Robert Parish of the famed Boston Celtics, Conor Mcgregor of the UFC and Robert Gronkowski of the New England Patriots.

On the other hand, we have alcohol. It is one of the most widely used drugs in the world and is a popular recreational activity. Alcohol is a simple molecule that enters the blood and is distributed throughout the body by the liver. Alcohol is categorized as a depressant, affecting the central nervous system and, like marijuana, helps individuals achieve a state in which pain tolerance and mental activities are affected.

Unlike marijuana, there are no studies of evidence of it being used as a performance enhancing substance, rather studies have shown it to have adverse effects on athletic performance by various measures (Ware). Such effects include that alcohol use cancels out the gains from workouts, prevents muscle recovery, and reduces endurance

(Vella). However, such effects are more commonly seen through heavy consumption or abusive use. Athletes such as Lebron James and Dwayne Wade publicly drink alcohol for a leisure activity, and have advocated for the moderate use of alcohol which reduces cardiovascular diseases, boosts metabolism and improves the immune system.

All in all, most studies that have been conducted are more focused on the prolonged effect of recreational drug use on athletes, but not nearly as much have been said of its consumption the night before an athletic contest. Additionally, we wonder what varying degrees of consumption can take a toll on an individual the next day. In general, players are not prohibited from spending a night out clubbing while on a road trip to Miami for concern of debilitating their athletic performance the following day. But should athletes be reconsidering the consequences of their decisions?

Our study aims to determine the effect recreational drugs such as marijuana and alcohol have on the performance of an individual in coordination and athletic abilities the next day. We wish to simulate these two commonly used recreational drugs among professional athletes to investigate whether consumption of these drugs enhance or hinder their athleticism. Hence, for our purposes, rather than examining the long term psychological or mental effects, we are more interested in the immediate consequences the next day.

II. METHODS

Participants

Participants were selected from the Island and from various cities and geographic locations by way of a random number assignment to all the cities. In doing so, we attempt to mitigate any effects of particular regions through randomization. After randomly selecting a city, we "hand-selected" participants that met our below criteria with as little bias as possible in an effort to emulate the process of randomization. However, we acknowledge that this selection process is not truly random sampling. Hence, our conclusions may not be applied to the entire population, but only to the sample involved.

Regarding our requirements, naturally, by way of our topic and treatments, we required participants to be of legal age (18). Further, since we hope to make our findings to emulate the behavior of professional athletes, we set our age range to be between 18-40, which we assumed to be the general age of most professional athletes. Equal number of males and female participants were sought out in order to ensure gender effects were not included in our studied response.

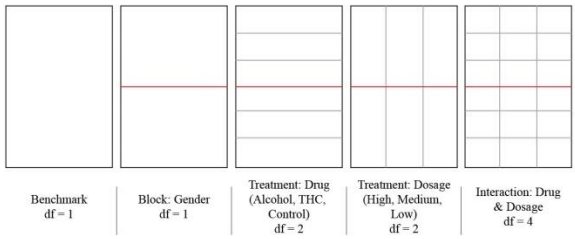
Design

We deployed a two-way factorial design with blocking and interactions in order to achieve higher efficiency and examine the effects of multiple factors in addition to the interaction of the two. By blocking on gender, we aim to decrease our sum of square errors by removing the effect of uncontrollable nuisance factors caused by gender that may taint the quality of our results.

The design parameters are as follows:

Response Variable	Coordination (ball bounces per minute) and Performance (100m sprint)		
Block: Gender	Male	Female	
Treatment: Drug	Control	THC	Alcohol
Treatment: Dosage	Low	Medium	High

The factor diagram is shown below:



Regarding the factor pertaining to drugs, we elected to focus our study on marijuana and alcohol, specifically tequila, as the two are perhaps some of the most likely and common recreational drugs that professional athletes indulge in (Ware).

Regarding dosage, we attempted to quantify varying degrees of drug use according to commonly perceived levels of high, medium, and low, as defined by the number of shots a participant will

drink or the amount of THC one will take. These different levels are intended to emulate the varying degrees of "hangover" athletes may feel the next day depending on varying levels of "intensity" from the day prior (Vella).

Our dosage levels were loosely determined by the CDC recommendations based on gender. For males, low doses corresponded to one blunt of marijuana or four shots; for women, one blunt or two shots. Medium doses corresponded to three blunts or eight shots for men and two blunts or four shots. High doses corresponded to five blunts or 12 shots for men and three blunts or six shots for women. Control groups were given water of approximately the same volume as the corresponding volume of shots (in mL).

As we wish to test the effects of drug use on sports performance, we measured the participants' ball dribbling ability to capture the participants' coordination and their 100m sprint in order to determine their athletic performance. Both responses were taken twice for each participant: before and after treatment.

Apparatus/Instruments

We assigned treatments randomly by way of random number generation performed in R. Measuring the number of ball bounces in a minute and their time to run a 100m dash were conducted with tools made available from the Island.

Statistical tools were also used to store the data (Excel), calculate the sample size (G-Power), and conduct our statistical analysis (R).

Procedure

We designed this experiment to last two days in order to determine the effects of recreational drug use on sports performance in the short-run. Since our experiment is time sensitive, we first recorded the pre-treatment response variables at 12 p.m. the first day. Then, we administered our treatments at around 9:30 p.m. the same day. We waited for passage of at least 12 hours for the participants to feel the hangover effect to following morning (Levine). Then, we measured our response variables for the same participants at the same time (noon) the second day.

Sample Size

By convention, we choose to apply a power of 0.8 ($1-\beta$) so that the probability of committing a type II error where we correctly reject a false null hypothesis is 0.2. Similarly, we also choose a significance level of 0.05 (α) so that the probability of committing a type I error where we incorrectly reject a true null hypothesis is small.

With an effect size of 0.25, we are able to determine our minimum sample size to be 196. As such, we plan to organize samples of 11 per group so that our experiment can be balanced, altogether forming 18 groups and a total of 198 participants.

Type of Statistical Analysis

Using the data that we have collected, we were then able to conduct our analysis by construction of a two-way analysis of variance. We performed multiple hypothesis tests with F-statistics within our treatments, interactions, and blocks in order to determine if the difference between response variables pre- and post-treatment is statistically significant. By inclusion of a control group, we are able to leverage a baseline statistic to be able to compare our treatment groups against.

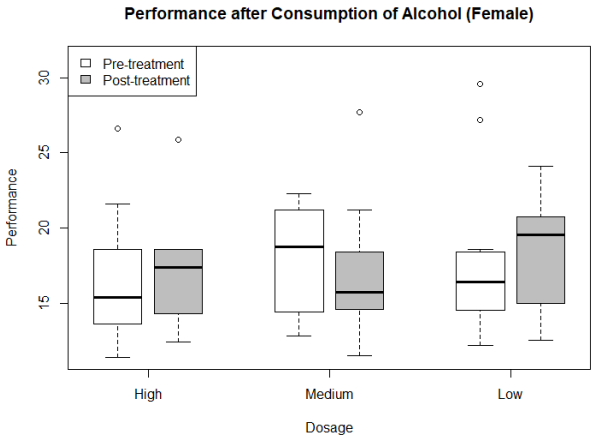
Additional tests of comparison of means such as Tukey HSD and Fisher's LSD were also conducted (see Tukey HSD subsection in Results below).

III. RESULTS

Initial Analysis

We begin our analysis by comparing the summary statistics for each of our groups and identifying any patterns or inferences. From the boxplots displayed below, we see that while some groups exhibit higher spread, the underlying message is that all the means appear approximately the same, suggesting that there is no difference in means between pre- and post-treatment groups.

The boxplots for the difference in performance for females are provided:



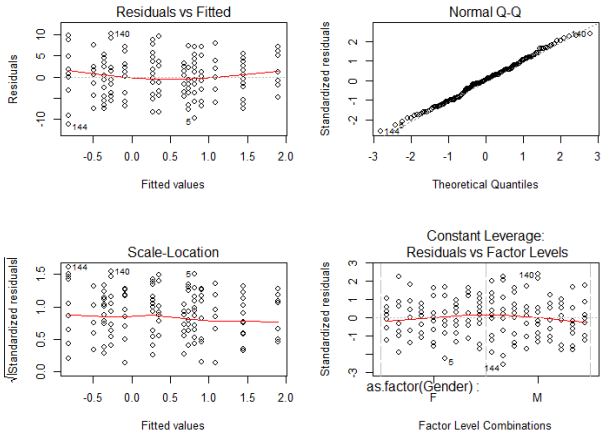
In regards to outliers observed above, we elected to leave those observations in since we determined that the number of bad leverage points was small and therefore, negligible.

Model Validity

Following this, we proceed to conduct a two-way ANOVA with blocking and interaction to observe any statistical significant effects from our treatments. Since we measured our responses in two categories (coordination and performance), we form two distinct models. The first model is follows the form:

$$y_{ijk} = \mu + \tau_i + \beta_j + (\tau\beta)_{ij} + \delta_k + \varepsilon_{ijk}$$

where y_{ijk} is the difference in coordination, as measured by the difference in number of ball bounces before and after treatment, of the *ijk*-th observation, τ_i is the effect of the *i*-th effect of the drug (i = 1 is alcohol, 2 is marijuana, 3 is control), β_j is the effect of the *j*-th dosage level (j = 1 is low, 2 is medium, 3 is high), δ_k is the effect of the *k*-th block (k = 1 is male, 2 is female), and $(\tau\beta)_{ij}$ is the effect of the interaction between the *i*-th drug and *j*-th dosage level.



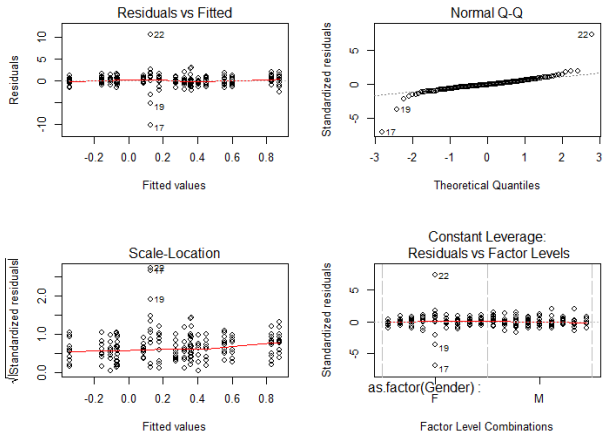
And the diagnostic plots are shown:

As for our second model, we have the following equation of the form:

$$z_{ijk} = \mu + \tau_i + \beta_j + (\tau\beta)_{ij} + \delta_k + \varepsilon_{ijk}$$

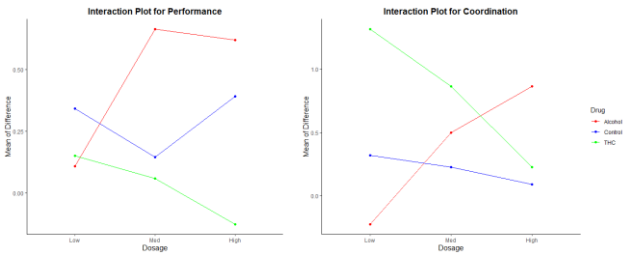
where z_{ijk} is the difference in performance, as measured by the difference in the 100m sprint before and after treatment, of the *ijk*-ith observation.

And whose diagnostic plots are as follows:



Interaction Plots

The following interactions plots for both coordination and performance are also shown on the right and left, respectively. In both instances, we would like to highlight the small scale on the axes and so despite indications of significant interaction, we proceed with our analysis with this thought in consideration.



ANOVA Tables

Our ANOVA table for coordination is as follows:

	Df	Sum Sq.	Mean Sq.	F value	Pr(>F)
Gender	1	68.0	67.960	3.4646	0.06426
Drug	2	12.3	6.126	0.3123	0.73213
Dosage	2	0.6	0.308	0.0157	0.98442
Drug: Dosage	4	26.7	6.687	0.3409	0.85010
Residuals	188	3687.7	19.615		

Similarly, our ANOVA table for our performance model is shown:

	Df	Sum Sq.	Mean Sq.	F value	Pr(>F)
Gender	1	9.04	9.0368	4.1530	0.04296
Drug	2	6.38	3.1904	1.4662	0.23343
Dosage	2	0.37	0.1852	0.0851	0.91844
Drug: Dosage	4	5.42	1.3550	0.6227	0.64687
Residuals	188	409.08	2.1760		

Multiple Comparisons Tests

We also conducted a Tukey HSD test to compare the mean differences of performance from drug treatments. The results are shown below:

	Diff.	Lower	Upper	p-value
Control-Alcohol	-0.171	-0.777	0.435	0.7830
THC-Alcohol	-0.436	-1.042	0.170	0.2081
THC-Control	-0.265	-0.871	0.341	0.5572

The Fisher LSD test also provided the same conclusion and so its results have been omitted to prevent redundancy, but can be found in our source code.

IV. DISCUSSION

To start, we check that our model assumptions are met. From our Residuals v. Fitted plots above, we see that in both instances, the errors exhibit constant variance and from our QQ plots, we see that they are also normally distributed. Hence, we our model assumptions are satisfied and we may proceed with our ANOVA tables.

In both measures, we found that the treatments, both drug and dosage, were statistically insignificant by measure of their F-statistic and p-value. This is consistent what what we saw in our boxplots. Additionally, the same conclusion could be said about their interaction and so we fail to reject our null hypotheses and conclude that drug, dosage, and their interaction do not have a statistically significant effect on an individual's performance or coordination.

However, we did find that blocking on gender was significant in the measure of performance, yielding an F-statistic of 4.1530 and a p-value of 0.04296. On a related note, we also saw that if we consider a significance level of $\alpha = 0.1$, then blocking on gender in the measure of coordination was also significant.

Our Tukey HSD and Fisher LSD tests also reported the same conclusions that there was no statistically significance in either performance or coordination pre- and post-treatment.

Therefore, based on our analysis with the two-way ANOVA, we can conclude that consumption of recreational drugs the night before did not have a statistically significant effect on an individual's performance or coordination the following day.

Some reasons for these surprising results are discussed in our conclusion.

Further Analysis

Since there results we obtained were to our surprise and inconsistent with the prior research that had been conducted (see references), we continued to apply different variations of our design to find any different conclusions. Since these analyses were done ad-hoc and we proceeded with our existing dataset. In doing so, we acknowledge that our analyses do not satisfy the sample size determinations described earlier and may not follow the same power.

Since we had recorded the age of our participants too, we attempted to block on age to see how our results may differ. Three age groups were selected with the intent of creating as evenly balanced groups as possible, although some groups had more participants than others. The resulting ANOVA table is shown below for coordination:

	Df	Sum Sq.	Mean Sq.	F value	Pr(>F)
Age	2	51.8	25.893	1.3071	0.2731

Drug	2	9.3	4.6726	0.2359	0.7901
Dosage	2	1.6	0.7754	0.0391	0.9616
Drug: Dosage	4	28.1	7.0182	0.3543	0.8408
Residuals	187	3704.5	19.810		

Likewise, the ANOVA table for performance is also displayed below:

	Df	**Sum Sq.**	**Mean Sq.**	**F value**	**Pr(>F)**
Age	2	0.37	0.1832	0.0821	0.9212
Drug	2	6.33	3.1629	1.4176	0.2449
Dosage	2	0.49	0.2460	0.1102	0.8957
Drug: Dosage	4	5.88	1.4689	0.6583	0.6217
Residuals	187	417.23	2.2312		

As such, what we find is that our results are consistent with what had discovered in our original study and that is there is no statistically significant difference in the coordination or performance of individuals after consumption of drugs the night prior.

We further attempt to test a two-way ANOVA with two blocks and interaction on coordination and share the following results:

	Df	**Sum Sq.**	**Mean Sq.**	**F value**	**Pr(>F)**
Age	2	51.8	25.893	1.3190	0.26988
Gender	1	54.4	54.441	2.7733	0.09753
Drug	2	9.6	4.823	0.2457	0.78244
Dosage	2	1.2	0.583	0.0297	0.97072
Drug: Dosage	4	27.0	6.738	0.3433	0.84847
Residuals	186	3651.3	19.630		

Our results here again indicate that neither treatments nor their interaction were significant.

Next, we deployed a repeated measures ANOVA to simultaneously test the effect of drug and dosage with the passage of time during two measurement periods. Each participant was measured twice, once before and once after treatment. The ANOVA table for the performance measure is shown below:

Error: Participant

	Df	**Sum Sq.**	**Mean Sq.**	**F value**	**Pr(>F)**
Drug	2	0	0.06	0.002	0.998
Dosage	2	14	7.03	0.221	0.802
Drug: Dosage	4	235	58.67	1.844	0.122
Residuals	176	5598	31.81		

Error: Participant:Time

	Df	**Sum Sq.**	**Mean Sq.**	**F value**	**Pr(>F)**
Time	1	6.75	6.750	7.400	0.00718
Drug: Time	2	2.35	1.175	1.288	0.27837
Dosage: Time	2	1.09	0.543	0.595	0.55260
Drug: Dosage: Time	4	1.16	0.291	0.319	0.86528
Residuals	176	160.53	0.912		

Again, we had found before, the effects of drug, dosage, and their interaction was not statistically significant.

V. CONCLUSION

Athletes are often held upon a pedestal, held to higher standards and are role models to many children. Our study aims to humanize these athletes because at their very core, are humans themselves and like the general public they indulge in the consumption of drugs such as tobacco, marijuana, and alcohol on a night out. Through our investigation we are hoping to find and examine the effects of THC and alcohol on athletic performance to determine if athletes' behavior and habits may affect their performance.

Our results showed that there is no significant relationship between coordination and performance before and after the consumption of recreational drugs on the following day. Through our analysis, all groups of mean differences between coordination and performance before and after recreational drugs did not have a statistically significant effect. Our ANOVA table solidifies this notion as we can see all our p-values are larger than our set significance value. Furthermore, we are able to capture a significant source of variability by blocking for gender as it was statistically significant in both measures, suggesting that by blocking on gender, that particular source of variability is not only controlled, but also reduced.

An important note, at first glance our interaction plot reveals that there was a sign of interaction between different dosages and drugs. Upon further investigation, running an ANOVA on our interaction terms we clearly see our interaction's p-value is not significant and that the plots only seemed to be significant due to the scaling of our y-axis.

To further improve upon our experiment for future studies we acknowledge the following considerations and limitations. First, we hypothesize there is limited programming in the Island to capture hangover effects similar to real world phenomenons. Also Islanders were not able to stay past midnight as they usually have a set programmed time to sleep. We also assumed that due to the scope and scale of the Island, there were no geographic variability effects within group variance, again unlike the real world where cultures and geographic location may affect one's response to the treatments.

Considerations for our future expansions upon our studies are considering the long-term effects of the drug treatments, as research suggests that effects of drugs may be better measured long-term. Lastly, measuring our response of coordination and performance based on two, short-lasting measures may not capture the full impact of prolonged night outs and usage of drugs throughout an athlete's career. It would be interesting to take samples of athletes before and after a prolonged use of drugs to see effects.

Applications of the results address the concerns some athletes may or may not have regarding their performance the following day, allowing for them to better understand the consequences of their decisions and also providing evidence that result in the change of negative perception of athletes going out for leisure activities.

VI. REFERENCES

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