

# WHOOP

## ALCOHOL AND THE COLLEGIATE WHOOP ATHLETE

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## Introduction

Alcohol use is known to be widespread on college campuses, a phenomenon that has been attributed to everything from the newfound lack of parental supervision, to the “Greek” System, to inconsistent or absent enforcement of underage drinking laws<sup>1</sup>. While many have come to pardon this behavior as part of the transition to mature adulthood, alcohol consumption by college students is far from harmless<sup>2</sup>. Alcohol’s danger to student athletes may be even greater than to the general student body because of its dual effect on athletic and academic performance.

Alcohol use can harm athletic performance in many ways, including short-term effects such as hangovers, which have been shown to **reduce athletic performance by 11.4%**<sup>3</sup>, and by long-term effects, such as injuries sustained while under the influence of alcohol. One study using 1421 athletes from 8 colleges representing all 3 NCAA divisions<sup>4</sup>, found that athletes with high-risk drinking behavior were 6.15 times more likely to have experienced an alcohol-related unintentional injury than were their peers exhibiting low-risk drinking behaviors. A second study agreed, reporting that athletes who drank at least once per week experienced an injury rate of 54.8% while their nondrinking counterparts experienced an injury rate of only 23.5%<sup>5</sup>.

Much has been written on the ergolytic (performance impairing) effects of acute alcohol consumption<sup>6</sup> even within a healthy and young population<sup>7</sup>, including interference with contractions of the heart’s left ventricle<sup>8</sup>, impaired temperature regulation<sup>9</sup>, hindered psychomotor skills<sup>10</sup>, reduced endurance<sup>11</sup>, and dehydration. However, little has been written about sustained effects of alcohol consumption after the user’s blood alcohol content has returned to 0.

The data reported on here was collected in 148 of WHOOP’s collegiate athletes representing 11 men’s and women’s teams and 6 unique sports. This report demonstrates the effect of user-reported alcohol consumption on various measures of performance and cardiovascular recovery. Unlike most attempts to elucidate the effects of acute alcohol consumption, which only show alcohol’s short-term effects (first day or so), this analysis additionally discusses the sustained effects of acute alcohol consumption over the 5 days following use.

This report therefore serves both to corroborate the current understanding of alcohol’s short-term effects and to introduce the **never-before reported-on sustained effect of alcohol consumption** in healthy, collegiate athletes.

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<sup>1</sup> National Institute of Health, 2015

<sup>2</sup> Hingson et al., 2009

<sup>3</sup> O’Brien, 1993

<sup>4</sup> Brenner et al., 2014

<sup>5</sup> Lyons, 1998

<sup>6</sup> Eichner, 1989

<sup>7</sup> Lang et al., 1985

<sup>8</sup> Strauss, 1991

<sup>9</sup> American College of Sports Medicine, 1982

<sup>10</sup> American College of Sports Medicine, 1982

<sup>11</sup> Bond et al., 1983

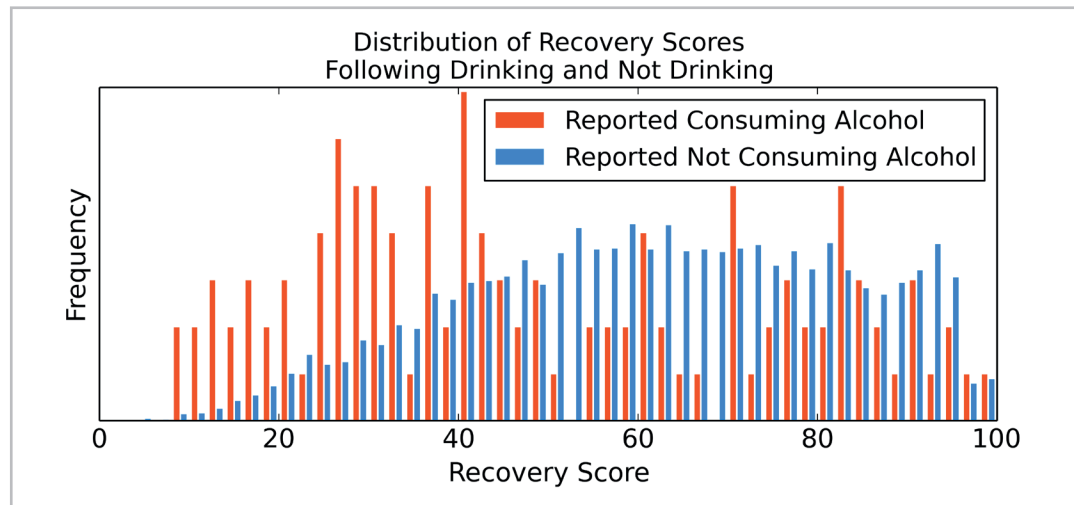


## Alcohol and Recovery

A central offering of WHOOP's "Always On" physiological monitoring platform is the Recovery Score, a function of heart rate, heart rate variability, and various derived measures of sleep quality and sleep duration sufficiency. The explanation and validation of the Recovery Score is the primary focus of several of WHOOP's recent publications<sup>12</sup>, and is therefore not repeated here.

In addition to measured parameters, WHOOP provides users with the option to provide subjective data via several daily surveys. One of the sleep survey's 7 questions reads: "Last night, did you have two or more alcoholic drinks within two hours of bedtime?" Users have only the ability to indicate yes or no, and are neither asked to nor given the ability to provide further detail. It is therefore important to point out that WHOOP does not attempt to validate these reports and does not differentiate in this data between moderate and heavy drinking. It should also be noted that the original intent of the data collected from this question was to analyze the acute effect of alcohol on sleep, WHOOP therefore does not collect data about drinking during the day or prior to the two hours before bedtime. These limitations should be kept in mind when interpreting the results presented here.

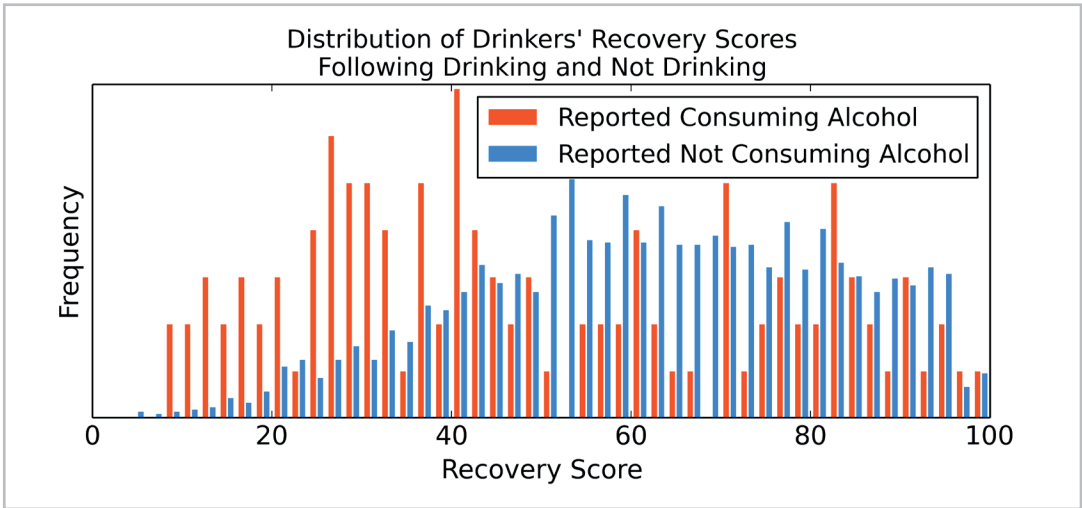
While the Recovery Score does not take user-reported alcohol consumption as an input, nor was it intentionally trained to predict alcohol consumption, it has nonetheless been shown retrospectively to correlate with user-reported alcohol consumption. **Figure 1** shows the histogram of the 6288 Recoveries with completed surveys (representing 73% of the total Recoveries recorded) from collegiate athletes between September 15, 2015 and February 22, 2016.



**Figure 1.** Distribution of Recovery Scores between 9/15/2015 and 2/22/2016 in WHOOP's collegiate athlete population. Blue scores represent scores earned following nights on which alcohol use within two hours of bedtime was not reported, while red scores represent scores earned following which users reported drinking two or more alcoholic beverages within two hours of bedtime. Because alcohol was reported prior to less than 1.9% of all Recoveries, the two histograms are normalized for improved clarity.

<sup>12</sup> Injury Incidence and the WHOOP Recovery Score, 2016; Heart Rate Variability – A Coach's Review of the Uses and Value of HRV Data in Athletes, 2016

During the period of time analyzed here, there were 118 user-reports of drinking at least two alcoholic beverages within two hours before bed, a behavior herein referred to simply as “drinking.” These reports came from only 44 (29.7%) of the 148 athletes considered in this analysis. In order to avoid confounding the effect of alcohol on Recovery with inter-athlete differences, the analysis presented in **Figure 1** was repeated, this time limited to only the scores attained by the 44 athletes who engaged in late-night drinking behavior at least once. The results of this analysis are presented in **Figure 2**.



**Figure 2.** Distribution of Recovery Scores since 9/15/2015 in the subset of WHOOP’s collegiate athlete population that reported drinking at least once. Blue scores represent scores earned following night on which alcohol use within two hours of bedtime was not reported, while red scores represent scores earned following which users reported drinking two or more alcoholic beverages within two hours of bedtime. As in **Figure 1**, the two histograms are normalized for improved clarity.

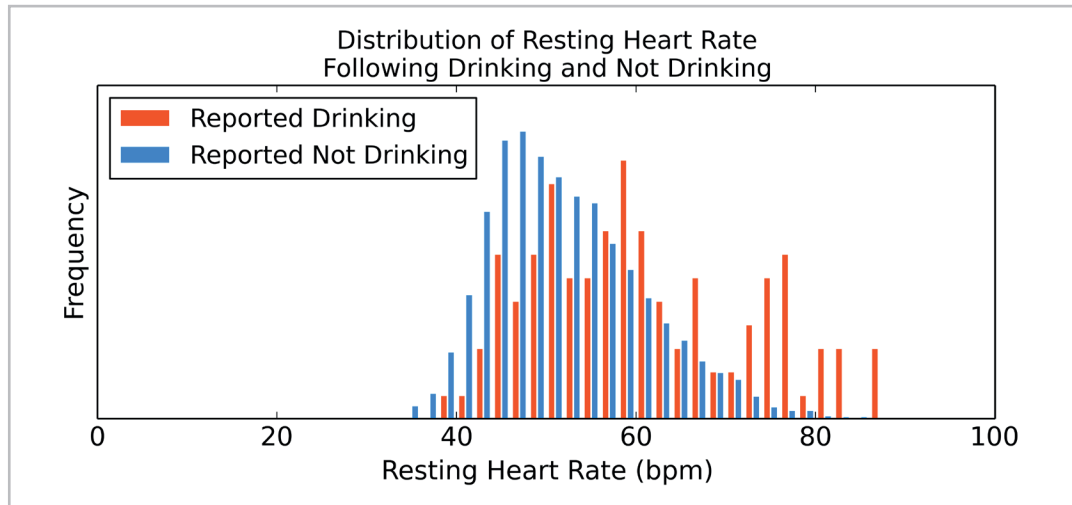
Perhaps unsurprisingly, the overall distribution of the 2579 Recovery Scores after which drinking was not reported (blue data presented in **Figure 2**) closely mimics that of the total population following non-drinking (blue data presented in **Figure 1**). **Table 1**, below, summarizes these differences.

	Average (%)	Standard Deviation
Recovery Scores in College Athletes	60.7	21
Recovery Scores in the non-drinking population	61.6	21
Recovery Scores in the drinking population following nights without drinking	61.7	20
Recovery Scores in the drinking population following drinking	48.8	25

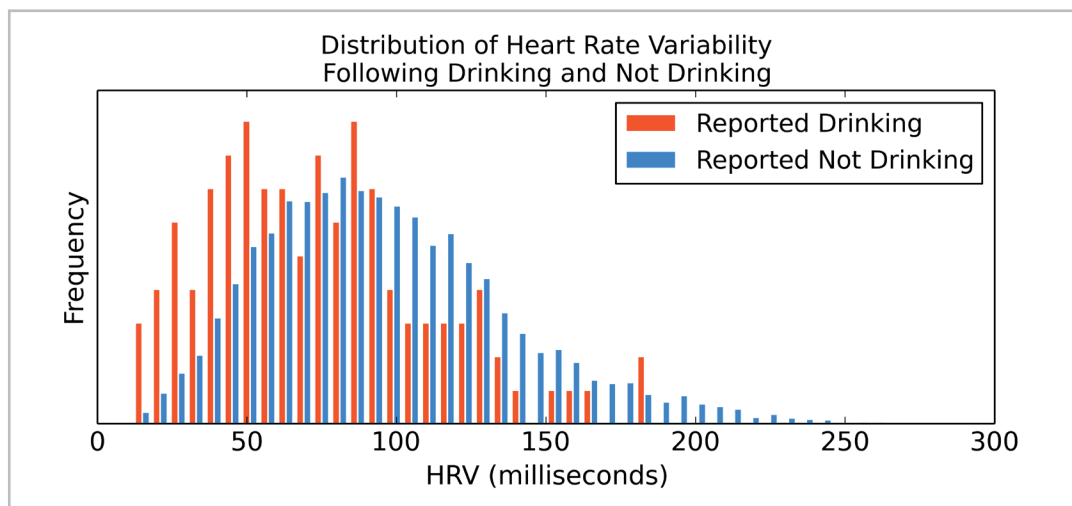
**Table 1.** Mean and standard deviation of Recovery Scores along various subdivisions of the WHOOP collegiate population.

### Resting Heart Rate and Heart Rate Variability

While the focus of this report is on the correlations between drinking and the WHOOP Recovery Score, it should be noted that heart rate and heart rate variability (HRV), the Recovery Score's two main inputs, both individually correlate with drinking as well. **Figures 3 and 4** show these results, which are additionally summarized in **Table 2**.



**Figure 3.** Normalized distributions of Resting Heart Rates following drinking (red) and not drinking (blue) in the WHOOP college athlete population.



**Figure 4.** Normalized distributions of Heart Rate Variability following drinking (red) and not drinking (blue) in the WHOOP college athlete population.

HRV is a measure of the fluctuation in the length of the time interval between successive heartbeats<sup>13</sup>. Although HRV presents as a feature of cardiovascular output, its source originates in the nervous system; HRV is therefore a valuable window into whole-body functioning, with distinct information from that provided by measurements of resting heart rate<sup>14,15</sup>. While there are many accepted methods of measuring HRV, WHOOP uses a method called rMSSD (root mean square of successive differences); the information presented in Figure 4 is therefore HRV in units of milliseconds calculated using the standard rMSSD formula<sup>16</sup>.

	After Not Drinking (Mean +/- Standard Deviation)	After Drinking (Mean +/- Standard Deviation)
Resting Heart Rate	51.8 +/- 9	60.2 +/- 12
Resting Heart Rate Variability	96.4 +/- 42	74.5 +/- 37

**Table 2.** Mean and standard deviation of heart rate variability and resting heart rate following drinking and not drinking in the WHOOP college athlete population.

The information presented in **Figures 3 and 4** and **Table 2** is especially significant in light of the large body of research demonstrating the correlations between these measures and athlete performance<sup>17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27</sup>, a topic that will be revisited further down in this report.

<sup>13</sup> Bilchick and Berger, 2006

<sup>14</sup> Garett et al., 2010

<sup>15</sup> Stauss, 2003

<sup>16</sup> Stein and Kleiger, 1999

<sup>17</sup> Achten and Jeukendrup, 2003

<sup>18</sup> Halson et al., 2002

<sup>19</sup> Vasterinen et al., 2011

<sup>20</sup> Kiviniemi et al., 2007 and 2009

<sup>21</sup> Plews et al., 2013

<sup>22</sup> Uusitalo et al., 1998

<sup>23</sup> Aubert et al., 2003

<sup>24</sup> Furlan et al., 1993

<sup>25</sup> Sandercock et al., 2005

<sup>26</sup> Garett et al., 2004

<sup>27</sup> Kenney, 1985



### Lingering Effects

After demonstrating that alcohol has a harmful effect on next-day Recovery, Heart Rate, and HRV, WHOOP data scientists next wanted to know how long this phenomenon persisted. To answer this, Recovery Scores from the 5 days after each user-reported drinking event were pulled. In order to be included in this portion of the analysis, a user had to record a valid Recovery Score on each of the 5 days after drinking and not report drinking again during this time. The second restriction was put in place to avoid confounding the effects of the first night of drinking with the effects of the second. From the 118 instances of drinking originally identified, 61 (52%) met both of these criteria.

In order to meaningfully analyze the Recovery trends following drinking, it was first necessary to establish what the expected values would be had the athlete not drank. This step was non-trivial because alcohol is only one of many factors that impacts Recovery; without controlling for these other factors, an accurate picture of alcohol's lingering effects would not be provided.

### Confounding Variables

In order to make meaningful conclusions regarding the relationship between drinking and athlete recovery over the next 5 days, it was necessary to first control for differences in circumstance. Here, "differences in circumstance" refers to everything from how much sleep an athlete got, where in the season the athlete currently is, how hard this week's training was, and whether or not the athlete had to travel or not for competition. These effects were controlled for by analyzing Recoveries relative to the athlete's non-drinking teammates during the same period of time. Conveniently, an athlete's teammates are necessarily at the same point in the academic year, the same point in the training schedule, and on the same competition and travel schedule as the athlete, making them an excellent control group.

### Day-of-the-Week Effect

Sleep has repeatedly been shown to have a strong effect on athlete performance and cardiovascular recovery<sup>28, 29, 30, 31, 32</sup>. If athletes were found to dedicate a similar amount of time to sleep from night to night, it could be assumed that the effect of alcohol on recovery would not be confounded by differences in time dedicated to sleep. However, what was actually found was that college students, even those who never consume alcohol, have very different sleep patterns on weekdays and weekends. **Figure 5** shows the distribution of time dedicated to sleep by day of the week in the 148 collegiate athletes considered in this study.

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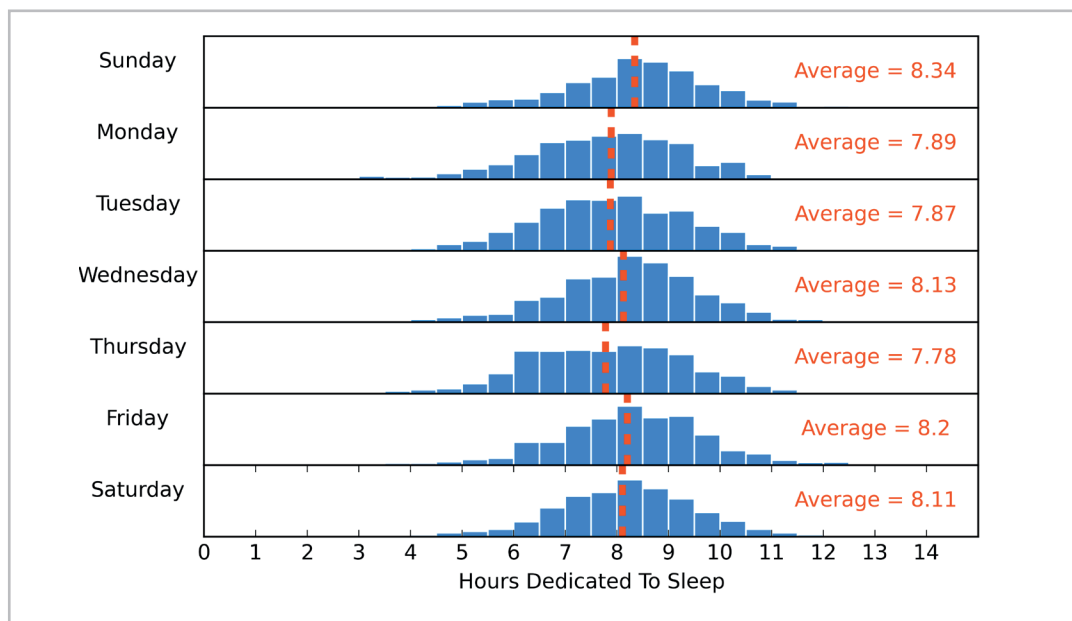
<sup>28</sup> Mah et al., 2011

<sup>29</sup> Sawka et al., 1984

<sup>30</sup> Martin et al., 1981

<sup>31</sup> Drewes, 1999

<sup>32</sup> Souissi et al., 2003

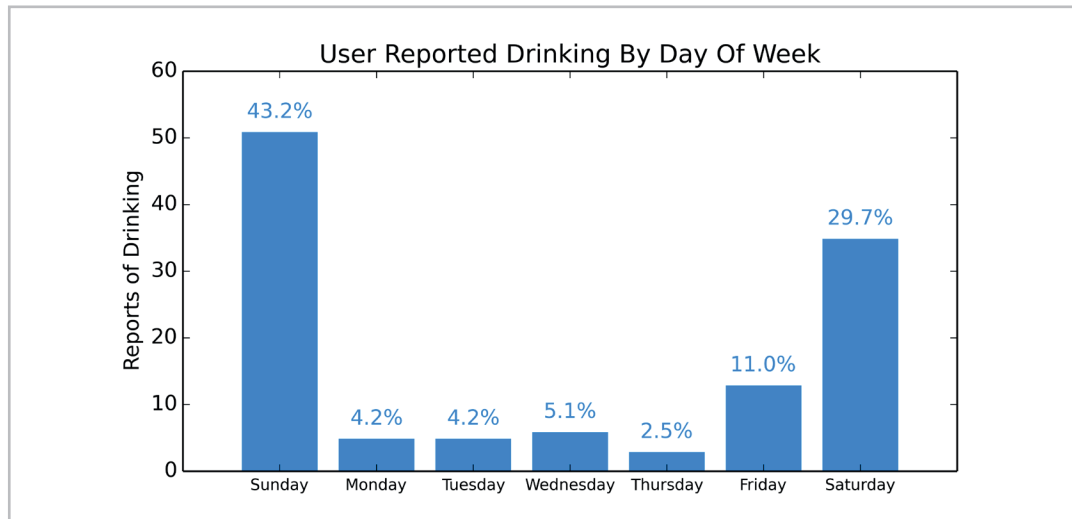


**Figure 5.** Distribution of time dedicated to sleep (in hours) by day of week. The dashed red line down the center of each histogram shows the average time dedicated to sleep for the indicated weekday. For added clarity, the average time is also reproduced in red on the right side of each row. Note that days here are labeled according to the day (in the user's local time zone) on which the sleep ended such that the "Sunday" histogram would also include a sleep that began on Saturday night before midnight.

The data presented in Figure 5 suggest that if athletes consciously or unconsciously compensate for alcohol's effect on Recovery by attaining extra sleep, monitoring how quickly Recovery bounces back to a user's baseline after a night of drinking may appear to happen artificially quickly. This would create the illusion of alcohol being differently disruptive than it truly is.

This concern is especially significant in light of the concurrent weekday-dependent pattern in alcohol consumption, in which the 118 instances of user-reported drinking primarily occurred on weekends (72.9%). Figure 6 shows the distribution of user-reported drinking by day of week.

The data presented in **Figure 6** means that simply comparing average recovery scores 1, 2, 3, etc. days after drinking to average recovery scores would not paint an accurate picture of the lingering effect of drinking on Recovery given the confounding impact of getting extra sleep the night after most drinking occurs.



**Figure 6.** Distribution of incidences of user-reported drinking by day of week. Note that days here are labeled according to the day (in the user's local time zone) on which the sleep ended such that the "Sunday" bar would also include a sleep that began on Saturday night before midnight and at 1 am on Sunday.

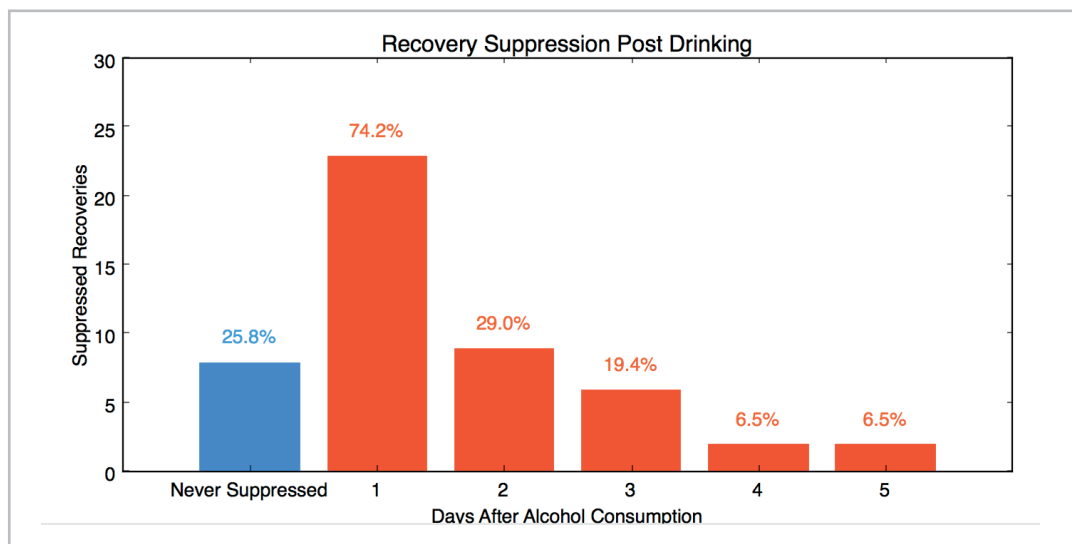
### The Team Effect

By analyzing an athlete relative to the Recovery Scores of his or her non-drinking teammates, and by making the assumption that the average athlete and the average member of the athletes' team have the same schedule, and therefore are experiencing the same effects of scheduling on Recovery, it was possible to normalize against the effect of scheduling on Recovery. Therefore, for each of the 61 instances of drinking followed by at least 5 days of not drinking, we also calculated the average Recovery Score of the athletes' non-drinking teammates' Recoveries. To be included in this portion of the analysis, a team had to have at least 3 athletes per day with valid Recovery Scores and completed surveys for which they did not report drinking. Because many of the teams included in this analysis are small, this reduced our sample size to 31 eligible events.

### Findings: Alcohol's Sustained Effect on Recovery

Because of the need to control for Recovery's many influencers, for the purpose of this report, a Recovery is considered to be lowered if it is lower than the team's average on a given day. For the 31 instances of alcohol consumption considered appropriate for this report, we tallied the number that were lowered on each of the 5 days following alcohol consumption.

**Figure 7** shows this distribution.

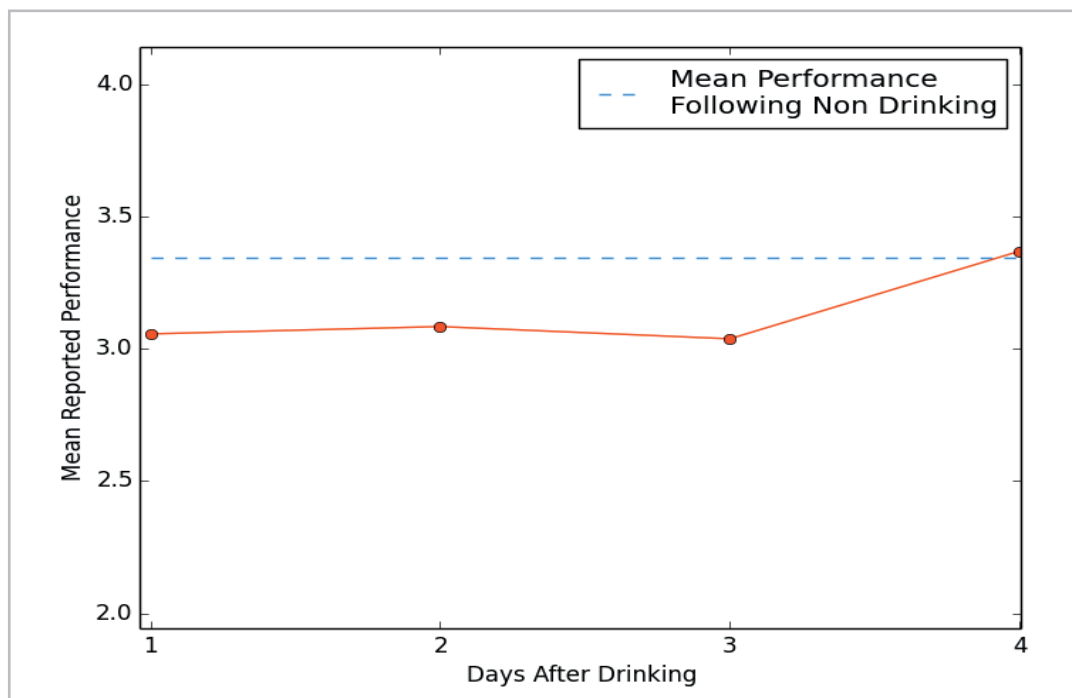


**Figure 7.** Distribution of Return to team average Recovery after drinking. The blue bar shows the number of drinking events after which the users' Recovery Score was immediately greater than or equal to his/her team's average. The data in red show the cumulative number of users who on 1 through 5 days after drinking had Recovery Scores below their team average, such that the athletes on day 4 had Recovery Scores that were lower than their teams' average 1, 2, 3, and 4 days post drinking. The numbers above the red and blue bars are the percentage of total analyzed instances that met the criteria indicated on the x-axis. The raw numbers are shown by the y-axis.

The analysis presented in Figure 7 may be an indication of inter-athlete differences in the long-term effects of alcohol consumption on Recovery. As mentioned above, WHOOP's alcohol usage data is collected in a binary manner, such that athletes either reported drinking 2+ alcoholic beverages or not. This means that WHOOP does not have further data on differences in quantity of alcohol consumed, sources of alcohol consumed, or the duration over which the drinking occurred. The inter-athlete difference in the observed amount of time to return to the team's baseline is therefore likely a combination of physiological differences in alcohol metabolism, differences in post-drinking behavior (diet, hydration, rest time), and differences in total alcohol consumed. Further research will be required to tease out the effects of each of these variables in isolation.

### Impact on Workout Performance

After demonstrating that Recovery Scores are suppressed for as many as 5 days after consuming alcohol, we next wanted to show the real-life implication of this result by showing that **workout performance was indeed suppressed after drinking**. In order to complete this analysis, the same cohort as in **Figure 7** was used. After each workout recorded using WHOOP, the WHOOP mobile application prompts the user with an optional 4-question survey. One of the questions asks the user to self-report their performance on a discrete scale from 1 (weak) to 5 (peak). For the study cohort analyzed here, the mean workout performance level reported is a 3.34/5. **Figure 8** shows the mean reported performance on workouts following reported drinking events.



**Figure 8.** Return to team average workout performance after drinking. The red line shows the average user-reported workout performance for workouts happening on the number of days after drinking indicated by the x-axis. The dashed blue line shows the average performance for the same athletes.

Notice how the average performance does not return to baseline until 4 days after the reported drinking event. This is significant for athletes considering drinking up to 4 days before an important athletic event for which they would want to maximize performance. This finding is also consistent with the data presented in **Figure 7**, given the Recovery Score's correlation with athletic performance.

## Conclusions

**The data presented here is the first to illustrate alcohol consumption's multi-day effects on objectively measured Recovery and subjective athlete performance**, a type of physiological analysis made possible by WHOOP's continuous monitoring technology. Using self-reported alcohol consumption data, data scientists at WHOOP were able to show that some athletes may experience sustained harmful effects for as many as 5 days after consuming alcohol.

Although self-reported data is common in behavior studies, we acknowledge that the results presented here may have been influenced by inconsistencies in reporting by athletes attempting to conceal their drinking or simply forgetting to log in. We therefore provide these early results as educational material for coaches, training staff, and athletes to use to understand the sustained effects of alcohol consumption on their ability to train and perform effectively. As the WHOOP athlete population continues to grow and collect more data on athlete performance, Recovery, and behavior, we will be able to repeat these analyses with larger sample sizes and hopefully be better able to understand the effect of this common behavior on both college athletes and the general WHOOP population.



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