THE IMPACT OF WHOOP ON USER BEHAVIOR

EMILY BRESLOW, LEAD QUANTITATIVE PHYSIOLOGIST AND ANALYTICS MANAGER
DEPARTMENT OF PHYSIOLOGY AND ANALYTICS
WHOOP, INC.

JUNE 21, 2016
# Table of Contents

Abstract .................................................................................................................. 2

Increased Time Dedicated To Sleep .................................................................. 3

Improved Sleep Hygiene .................................................................................. 6

Implications for Athlete Performance ............................................................... 10

Implications For Injury and Sickness ................................................................. 11

Conclusion ......................................................................................................... 13

References ......................................................................................................... 14
Abstract
WHOOP’s Physiological Monitoring Technology provides athletes with an unprecedented amount of insight into how their bodies are adapting to training programs, the sufficiency and efficiency of their sleep, and more broadly, how well their body is adapting to environmental demands.

WHOOP collects multiple streams of continuous bio-data with high sampling frequency, including heart rate, heart rate variability, electro-dermal activity, ambient temperature, and 3D acceleration. Using advanced digital signal processing and data analytics algorithms, WHOOP transforms this data into continuous, actionable feedback and behavioral recommendations for the user.

WHOOP’s goal is that such accurate and consistent data will empower athletes to make smarter training decisions, such as increasing intensity and strain when their bodies are physiologically prepared for positive adaptations, and to make smarter “off-field” decisions like going to bed earlier to offset the accumulation of sleep debt, or kicking an after-dinner caffeine habit to reduce sleep latency and improve sleep quality.

Since the early phase launch of the WHOOP technology, the company has received numerous anecdotal reports from athletes stating that they never realized how little sleep they were getting or the extent to which their pre-sleep behaviors negatively impacted their sleep, and that, in response to WHOOP educating them through its platform, they have begun getting more sleep. Intrigued by the frequency of these reports, we sought to verify and quantify this phenomenon. The findings, interpretation of their meanings, and implications for athletic performance are introduced in this paper for coaches and athletes to review.
Increased Time Dedicated To Sleep
The first stage of analysis sought to confirm that, over time, WHOOP athletes indeed dedicate more time to sleep each night.

On September 15th, 2015, 8 NCAA Division 1 teams joined WHOOP. These teams represented swimming, track and field, long distance running, basketball, tennis, squash, and cross country skiing. Each morning, upon waking up, these athletes were provided with an analysis of their sleep which, among other things, included (1) the total time they dedicated to sleep, (2) the total amount of sleep they got, (3) the amount of time it took them to fall asleep, (4) the number of times their sleep was disturbed, (5) the distribution of time spent in each of sleep’s stages, (6) the number of sleep cycles the user completed, and (7) the amount of sleep the user needed. All this information is boiled down to a Sleep Performance Score - a score from 0 to 100 that quantifies how much of the sleep the user needed he or she actually attained. The validation of these scores can be found elsewhere, here we focus on one question only:

Did making users aware of these metrics in turn encourage users to improve them?
For each day between September 15th, 2015 and January 22nd, 2016, the day on which this analysis was completed, we averaged the time spent in bed by the combined 119 athletes who make up the aforementioned 8 teams. Figure 1 shows these averages plotted as a function of date. From it, we see that within this population, the average time dedicated to sleep per night increased by 0.69 hours (41 minutes) over the 129 days analyzed here.

Figure 1. Time dedicated to sleep per night over 129 days. The blue trend line shows each day’s average time in bed across the NCAA Division I collegiate athletes who joined WHOOP on 9/15/2015. The dashed red line shows the trend generated using a standard least square linear fit across the entire available data set.
In order to demonstrate that this phenomenon is not an artifact of impressive improvements in only a few high-performing athletes, Figure 2a shows a histogram of the change time dedicated to sleep in each athlete. Here, change is defined as the difference in hours dedicated to sleep at the endpoints of the linear trend line fit to the user’s available data between September 15th, 2015 and January 22nd, 2016. Note that athletes with fewer than 15 sleeps were excluded on the basis of not having a sufficient number of samples.

![Figure 2a. Distribution of the change in time dedicated to sleep in WHOOP collegiate athletes over their first 129 days on WHOOP. Changes in time dedicated to sleep are shown aggregated in bins 10 minutes wide.](image)

Although, as in Figure 1, there is a wide distribution in the actual data, there is a clear trend towards increased time dedicated to sleep. Interestingly, the data is not normally distributed, there appears to be a large cluster around 0 and a second large cluster around 1.3 hours of increased sleep. One possible explanation for the large number of athletes who made no gains or only minor gains in time dedicated to sleep is that there as a subset of athletes who were already getting a sufficient amount of sleep at the beginning of the period analyzed here.

In order to test this theory, WHOOP’s Data Science team separated the data into two groups - those averaging **7.9 or more hours** dedicated to sleep per night at the beginning of the study, and those averaging **fewer than 7.9 hours** dedicated to sleep at the beginning of the study. The data was split on 7.9 hours because that was the average starting point of the whole population. Figure 2b and 2c show the resulting distributions.
The athletes shown in Figure 2b, who began their time on WHOOP averaging fewer than 7.9 hours dedicated to sleep per night, averaged an increase of 52 minutes in bed per night, while the athletes shown in Figure 2c, who began their time on WHOOP averaging 7.9 or more hours dedicated to sleep per night, averaged an increase of 8 minutes in bed per night.

As hypothesized, Figures 2b and 2c show that athletes who began their time on WHOOP averaging fewer than 7.9 hours dedicated to sleep per night increased their time dedicated to sleep by more than did the athletes who were already making an adequate commitment to sleep when they joined WHOOP.

These findings make the results presented in Figure 1 even more compelling by showing that the greatest improvements in time dedicated to sleep occurred in the subset of users most in need of the change.
**Improved Sleep Hygiene**

After revealing that the cohort of athletes analyzed above had made an increased commitment to sleep by increasing their nightly time in bed, we next sought to see if they made any other sleep-positive behavioral changes in their first 129 days. To do this, we used the data collected via our morning sleep survey. The sleep survey asks athletes to self-report on various pre-bed activities by answering yes or no to each of 8 questions, including (1) Did you have 2 or more caffeinated beverages within 4 hours of bedtime? (2) Did you have 2 or more alcoholic beverages within 2 hours of bedtime? and (3) Did you work on screened device while in bed? These questions were chosen because of the extensive amount of research demonstrating each behavior’s deleterious effects on sleep.

For each of these behavior-related questions, we queried the database for each day’s total number of affirmative and negative survey responses. The following three figures show the total number of surveys indicating no (meaning the user reported not doing the behavior in question) in blue and the total number of surveys indicating yes (meaning the user did report doing the behavior in question) in red stacked above the number of negative-responses. Above the stacked bar chart, circled in red, is the percentage of total responses that were “yes” aggregated in month long-chunks starting on the 15th of September, 2015.

![User-Reported Nighttime Caffeine Consumption By Date](image)

**Figure 3.** Distribution of the incidences of athletes reporting consuming at least two caffeinated drinks within four hours of bedtime over their first 129 days on WHOOP.
Notice that after joining WHOOP, these athletes reduced their late-night caffeine consumption by 84%, reduced their alcohol consumption by 76.8%, and reduced the use of screened devices in bed by 12.4%.

**Figure 4.** Distribution of the incidences of athletes reporting consuming at least two alcoholic drinks within two hours of bedtime over their first 129 days on WHOOP.

**Figure 5.** Distribution of the incidences of athletes reporting working on a screened device while in bed over their first 129 days on WHOOP.
Implications for Next-Day Athlete Performance

While our athletes sleep, WHOOP records resting heart rate and resting heart rate variability measures. These measures have been repeatedly shown to correlate with same-day athletic performance\(^{1,2,3,4,5,6,7}\). To demonstrate the value of the above-demonstrated behavioral improvements, we next sought to show that concurrent with the increase in sleep and improvements in sleep hygiene, there have been improvements in resting heart rate (Figure 6a) and resting heart rate variability (Figure 6b).

The data presented in Figure 6 shows that the average collegiate WHOOP athlete’s resting HR decreased by 4.4 beats per minute while the average heart rate variability increased by 8.3 milliseconds. Both of these changes constitute evidence of significant increases in cardiovascular fitness that are expected to correlate with increased athletic performance as well.
Implications for Injury and Sickness

In 2011, a research study out of Stanford University demonstrated that extending sleep in college basketball players increased their free throw percentage by 9%, their 3-point field goal percentage by 9.2%, decreased their sprint times by 4.3%, decreased the incidence of injury, and subjectively improved mood, conditioning, recovery rate, and weight training. While at present, we do not have the data to verify the presence or absence of all of these phenomena in the WHOOP population, we were able to demonstrate that rate of injury incidence decreased alongside the increase in time in bed.

Each morning, WHOOP athletes are prompted with a short recovery survey via WHOOP’s mobile application. In it, they are asked to report on their subjective feelings of sleepiness on a 4-point discrete scale, their subjective levels of soreness on a 4-point discrete scale, and yes/no to each of (1) are you injured, (2) are you sick, and (3) are you stressed? For the athletes included in this analysis, we queried the database for the date of each report of injury - a total of 98 between September 15, 2015 and January 22, 2016. Figure 7a shows the distribution of these reports of injuries by day (blue bars) with month-by-month totals indicated above in red. Note that month-by-month data is aggregated such that each month runs from the 15th day of the previous month through the 14th day of the next month, for example, the first number shown represents September 15th through October 14th. In order to demonstrate that the decrease in injuries is not merely an artifact of a decrease in survey response compliance, Figure 7b shows the number of reported injuries per day as a fraction of the total surveys completed. Notice how the trend in percent of surveys indicating the presence of an injury mimics the trend in total reported injuries shown in Figure 7a.

Figure 7a. Distribution of user-reported injuries over time on WHOOP. Blue bars indicate the number of reported injuries on each day, while the circled red numbers on top indicate the total number of injuries in each completed 30-day period.
The data from Figure 7b shows that over the first 129 days on WHOOP, the athletes studied here reduced the rate of injury reports by 60%.

The findings in Figures 7a and 7b are consistent with the findings reported by Mah et al., in that the number of injuries decreased as time in bed increased in these athletes.

While Mah et al.’s study did not explicitly mention reduction in incidences of sickness in the participating athletes, she does mention improved subjective physical and mental wellbeing. We therefore next repeated the same analysis process using the survey data we gathered on user-reported sickness. The resulting analysis, Figures 8a and 8b, is shown below.
Figure 8a. Distribution of user-reported sickness over time on WHOOP. Blue bars indicate the number of athletes reporting sickness on each day, while the circled red numbers on top indicate the total number of injuries in each completed 30-day period.

Figure 8b. Distribution of the incidences of athletes reporting feeling sick over their first 129 days on WHOOP. Blue bars indicate the number of completed surveys in which sickness was not reported, red bars above the blue bars indicate the number of additional surveys completed indicating a report of sickness, such that the height of the blue and red bars together indicate the total number of surveys completed in this population on each day. The red, circled numbers on top indicate the percentage of completed surveys in the indicated month that included a user-reported illness.
Over their first 129 days on WHOOP, the athletes included in this analysis saw a reduction in the rate of self-reported illness of 53%.

The athletes included in this study were in the state of Massachusetts for the majority of the time analyzed here. The data presented in Figures 8a and 8b are therefore even more interesting because they seem to buck the trend of common diseases, like the common cold and flu, which, in this part of the country, rise steadily through the fall and peak in the early winter\textsuperscript{iv}. However, here, we see that while incidences of these diseases were very likely increasing on the college campuses on which these athletes live, their own prevalence of sickness decreased dramatically.
Conclusion

By equipping each athlete with the information he or she needs to make quantified behavioral decisions, WHOOP aims to empower athletes to take ownership of their fitness and performance.

The data presented in this paper demonstrates that the use of WHOOP Physiological Monitoring Technology may have a positive impact on athlete behavior by showing that as time using the platform increased, the athletes analyzed here dedicated more time to sleep while also decreasing the frequency of three behaviors that negatively impact sleep. We also demonstrated the direct value-add of these behavioral modifications, by demonstrating the presence of concurrent decreases in the prevalence of both injuries and illnesses, the increased heart rate variability, and the decreased resting heart rates.

Further analysis is ongoing by WHOOP’s analytics team to validate other findings presented by Mah et al., including correlating improved sleep behaviors with improvements in in-game performance.

While the initial results are still only preliminary, the trending behavior modification and injury reduction statistics are exciting.
References


xii Vesterinen V, Häkkinen K, Hynynen E, Mikkola J, Hokka L, and Nummela A (2011) Heart

