TRAINING WITH WHOOP: USING RECOVERY AND STRAIN TO UNLOCK YOUR POTENTIAL

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OBJECTIVE

There is no shortage of readily available material offering tips and tricks on building training plans. The problem is, even if you limit yourself to peer-reviewed academic publications, not all material seems to agree. In response to all the confusion out there, WHOOP put together this paper. In it, we review three things; (1) what we actually know vs. what is still theory, (2) how WHOOP uses this information to understand your data, and (3) how you can use WHOOP to unlock your fitness potential.

INTRODUCTION

Everyone knows that you have to train to increase fitness and performance, but there is such a thing as too much of a good thing; training too much harms performance just as much as not training enough does. Therefore, top athletes are constantly engaged in a delicate balancing act between overdoing it — risking overtraining and injury — and under-doing it — leaving unrealized performance gains on the table[1,2,3,4]. The motivation behind creating WHOOP[5] was the realization that our bodies were full of information that could help us navigate this fine line, if only we knew how to listen.

WHOOP exposes this information to our members via two primary metrics: Strain and Recovery. In the sections that follow, we get into the science behind these features and discuss how to use them in order to not only understand the impact of training on your body, but also how to use them prescriptively to plan your training.

UNDERSTANDING WHOOP STRAIN

WHOOP Strain, reported on a scale from zero to 21, measures the total cardiovascular load experienced over a specified period of time - such as a workout or day - normalized such that a 21.0 represents the maximal cardiovascular load that could be attained in a day. Put simply, Strain answers the following question: “As a function of the total amount of cardiovascular load I could have possibly placed on my body today, how much load did I experience during this period?” Formulated thusly, Strain differentiates itself from the myriad of alternative measures[6] of load in that it does not attempt to directly model external load (things like steps taken, miles ran, etc.) but rather measures what that load meant to you. If two athletes complete the same activity, for example, they both run the same 8-minute mile, they are almost guaranteed to receive different Strain scores because physiological state going into the workout and physiological response to the workout are this algorithm’s only inputs.

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1 Rowbottom, 2000
2 Turner, 2011
3 Plews et al., 2012
4 Budgett, 1998
5 http://www.startupsense.net/blog/ep-161-interview-with-will-ahmed-founder-of-whoop
6 Halson, 2014

By monitoring cardiovascular response to load rather than load itself, we are able to account for contributors to fatigue that external measures of load simply cannot account for, such as the increased effort required to exercise when it's hot[7]. Perhaps even more valuable though is the ability to capture sources of Strain that are impossible or impractical to measure via traditional methods, such as emotional stress[8] or the minor loads of everyday life, like grocery shopping. While a healthy, fit athlete might not consciously register the significance of grocery shopping, the reality is that over the course of a day, individually negligible components can add up to something non-negligible, and monitoring them can improve the accuracy of all algorithms that consider load as an input. In previous work[9], we demonstrated using our own data that non-workout Strain is not only practically significant, but is also larger than you might have thought.

UNDERSTANDING WHOOP RECOVERY

WHOOP Recovery, reported on a scale from zero to 100 percent, measures the body's ability to adapt to a training stimulus. Development of the Recovery algorithm was largely inspired by the finding that there exists an inconsistent "dose response to training"; meaning how hard I train is only one of multiple factors which determine my physiological adaptation (how much more fit I become)[10]. This prompts several questions, most significantly: what else determines my adaptation, and how do I maximize it?

While we do not yet know all of the factors that determine a given athlete's physiological adaptation to training, we do know quite a bit, and leveraged this information to develop the Recovery algorithm. Interestingly, many of the things people assume are strong determinants are only weakly relevant; for example, one study found that only 11% of the differences in training adaptation can be attributed to demographic information such as age, gender, and baseline fitness level[11]. The rest of this section describes our understanding of the relationship between training load and subsequent physiological adaptation.

Most of what we know comes from the work of Dr. Kiviniemi and his team in Finland, and from the work that later built on his work, such as that of Dr. Daniel Plews and his team in New Zealand[12,13,14]. In 2007, Kiviniemi and his team published a paper in which he concluded that athletes who adapted their daily training plan to HRV measurements taken before beginning exercise increased their fitness more than did a control group, even though total training load was equivalent[15].

To demonstrate this phenomenon in our own data, we looked at 1579 WHOOP users during overreaching training periods - periods of 4 to 14 days during which their Strain averaged around 15 on our 0-21 scale. We then looked at what happened in the week following the overreaching period and divided the athletes into two groups - (1) those who got more fit (n=706) - ie: their training resulted in their fitness improving, and (2) those who got less fit (n=873) - ie: their training left them worse off than they started. Fascinatingly, the biggest difference between those who got less fit and those who got more fit following the overreaching period was HRV during the overreaching period.

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[7] Maughan, 1999
[8] Akselrod et al., 1981
[9] Allen and Breslow, 2017
[10] Vasterinen et al., 2011
[11] Bouchard and Rankinen, 2001
[12] Plews et al., 2012
[13] Plews et al., 2014
[14] Buchheit et al., 2014
[15] Kiviniemi et al., 2007

The average athlete who became less fit had an HRV during the overreaching period that was 0.4 standard deviations below their recent baseline, while the average athlete who became more fit had an HRV during the overreaching period that was 0.2 standard deviations above their recent baseline. A t-test to confirm the significance of these differences had a p-value of 10^{-21}. Importantly, those athletes who experienced positive adaptations actually had higher average Strains than did those athletes who experienced negative adaptations (15.2 vs 14.4); meaning this difference is not explained by the negative adaptation athletes working harder and therefore burning out at greater rates. Additionally, there was no meaningful difference in total sleep time, with both groups averaging just under 7 hours per night. This finding is therefore consistent with the Kiviniemi findings reviewed above.

What our work, and the work that inspired it, together come to suggest is that a non-negligible determinant of our response to a training stimulus may be explained by HRV prior to training. This is exciting because it may mean that by saving our hardest workouts for days on which we are most ready to adapt to them, we can workout less and experience greater gains, freeing up precious time for other pursuits. It is worth noting that the WHOOP research presented here is observational, and the relationship between HRV during the overreaching period and cardiovascular fitness in the subsequent days has so far only been shown to be correlative; further studies would be required to prove a causal relationship.

PUTTING IT TOGETHER

PERFORMANCE = FITNESS - FATIGUE

Athletic performance is generally understood to follow "Bannister's Fitness-Fatigue Model[16]," which essentially says the following:

Performance = Fitness - Fatigue[17,18]

Put simply, fitness determines the upper limit of how we perform, but actual performance is limited by current levels of fatigue. Even to athletes unfamiliar with Bannister's work, his findings seem intuitive: an elite athlete will not perform at an elite level when totally run down and an untrained athlete will not perform at an elite level no matter how well rested.

While the theory presented by Bannister and his team seems simple, actually applying his formula is anything but. As soon as we try to take this work from the theoretical to the applied, we are faced with nontrivial questions such as "how many units of fatigue is 'I'm tired but could probably do another set'"? Or "how many units of fitness is 'I run a 5-minute mile'"? Bannister and his team don't provide answers to these questions, but thankfully our bodies do.

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[16] Bannister, 1975
[17] Morton et al., 1990
[18] Turner, 2011

HRV TO THE RESCUE

Heart rate variability (HRV) is a measure of the fluctuation in the length of the time interval between successive heartbeats[19]. Although HRV presents as a feature of cardiovascular output, its source originates in the autonomic nervous system; HRV is therefore a valuable window into systemic well-being with distinct information from that provided by measurements of resting heart rate[21,22]. HRV has been shown to correlate with both subsequent athletic performance and the previous day's training load, and as such, when monitored regularly and reliably, can be considered a reliable indicator of an athlete's fitness/fatigue balance[23,24,25,26,27,28]. HRV is able to encode information on both sides of the performance equation because what it is really telling you is **what percentage of your body's total ability to do work is currently allocated.**

Put simply, our bodies have a certain capacity to work. At any given time, some amount of that capacity is being used for the necessary maintenance of physiological processes, like breathing, and what's not pre-allocated to these tasks is available for voluntary processes, like going for a run. All kinds of physiological needs put demands on our resources: when it's hot we use resources to keep ourselves cool, when we are sick we use resources to power our immune system, after exercise we use resources to repair and rebuild muscles. The more demands we have, the fewer are left over to put towards athletic performance. Availability of physiological resources manifests in HRV because the more we have unallocated, the more balanced the autonomic nervous system's two branches will be. As we allocate more and more resources, the sympathetic (activating) nervous system becomes increasingly dominant to manage these demands, thus decreasing the balance between it and the parasympathetic (deactivating) nervous system.

ACTIONING THE INSIGHTS

In the short term, total available resources are fixed and resources are allocated in priority order, meaning once all resources are allocated lower priority demands are simply denied. Understanding this is important to understanding how to put together a multi-day training plan. If I work out today, I will create demands on my resources; such as a need to repair damage done to muscles and to replace spent glycogen. If my body has available capacity to handle these demands, it will, and if not, it will not. The next day, whether or not those demands have been addressed will determine if I am now exercising on glycogen-depleted muscles or glycogen-replete muscles. This difference will have a huge impact on how I perform.

Since we first launched, WHOOP Recovery has removed the guesswork from determining your body's daily capacity to do work. Recently, we added another vital piece of information to this equation by introducing Training Zones, which help WHOOP users predict next-day Recovery based on today's Recovery and Day Strain. In the section that follows, we dive into the work that went into developing this feature.

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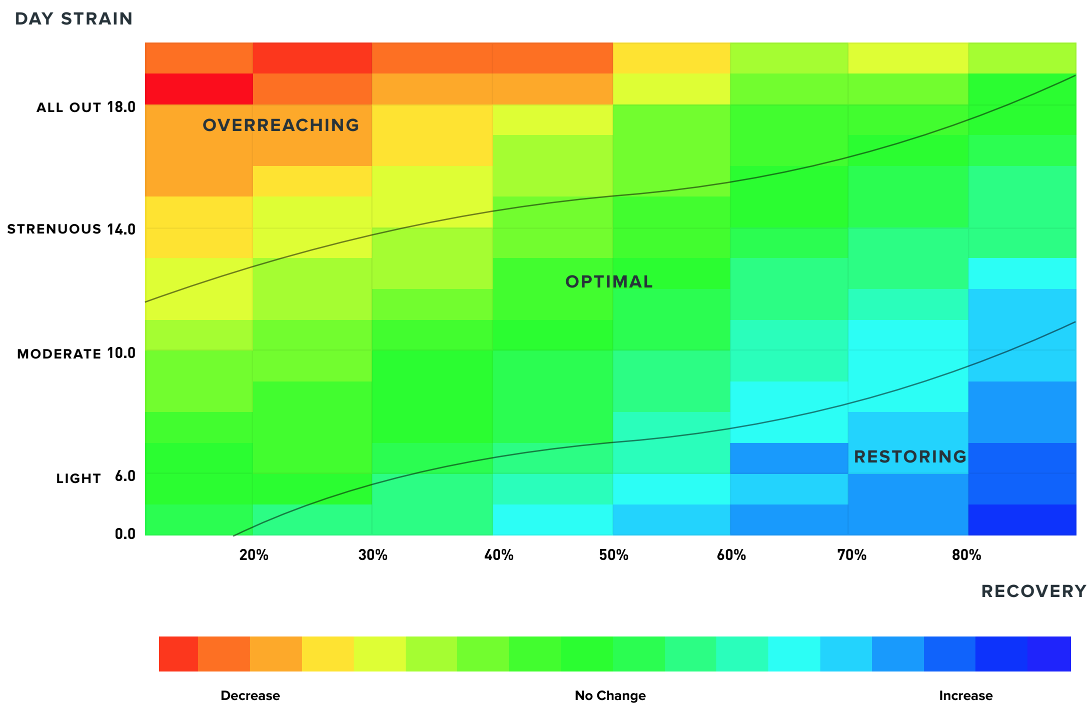
19 Bilchick and Berger, 2006
20 Uusitalo et al., 1998
21 Stauss, 2003
22 Garet et al., 2010
23 Earnest et al., 2004
24 Stanley et al., 2013
25 Hynynen et al., 2010
26 Kiviniemi et al., 2007
27 Plews et al., 2014
28 Hautala et al., 2009

WHOOP TRAINING ZONES

In order to make it as straightforward as possible to interpret trends in WHOOP Recovery and Strain, WHOOP introduced **Training Zones**, which classify combinations of Strain and Recovery into one of three designations:

(1) Overreaching, (2) Optimal, or (3) Restoring. To create the zone boundaries, we analyzed nearly one million samples taken from our users between September 2017 and June 2018. From each sample, we looked at the Recovery and Strain experienced by a user and the following day's HRV relative to baseline by using the same baselining method we use in calculating Recovery. We then binned samples based on their Recovery/Strain data and calculated the mean impact on HRV for each bin. Finally, the whole grid was divided into three zones based on the direction of the expected change in HRV. The Optimal Training Zone represents values of Recovery and Strain for which the typical WHOOP user's next-day HRV is not statistically different from their recent baseline. The Overreaching Zone covers the Recovery/Strain combinations after which users typically experience next-day HRV values below their recent baseline. Conversely, the Restoring Zone represents the combinations of Recovery and Strain that typically lead to next-day HRV values above their recent baseline.



In the figure above, the grid of all possible Recovery/Strain values are color coded based on the expected change in HRV relative to baseline, with the greatest increases shown in the darkest blue and greatest decreases shown in the darkest red.

The data presented above is consistent with the results presented earlier. Strain alone doesn't determine physiological response, but rather readiness to take on Strain, as measured by Recovery, meaningfully impacts how we respond to training. To put this in the terms used above, when we have available capacity to adapt to a training stimulus, we are more likely to fully recover from it by the next day than we are when we work out, despite having relatively few resources that can be allocated to workout adaptation.

This feature therefore enables more intelligent training than would be possible without reliable daily HRV readings. One may counter that carefully designed training plans can account for the expected fatigue and associated decrease in preparedness following intense exercise, thereby obfuscating the need to for a wearable. However, human physiology is complex, and physical and emotional stressors beyond exercise—like work and travel — can have a negative effect on performance.[29,30] Conversely, recovery-promoting behaviors like sleep, hydration, and stress management can increase performance by causing fatigue to decay at greater rates.[31,32]

The WHOOP Always On philosophy recognizes that even the most elite athletes don't turn off when practice ends and what happens the rest of the day can be relevant. By monitoring HR and HRV continuously, all contributors to "fatigue" are captured by Day Strain and real readiness is captured by Recovery, instead of formulaically predicting the rate of fatigue's decay. Therefore, the training impact predicted by Training Zones is more robust than could possibly be achieved by a model which only considers relevant what took place during the workout.

PUTTING THE TRAINING ZONES TO WORK

Which is better, 90 minutes of yoga or 2 hours of trail running?

Hopefully that question sounded completely ridiculous; "better" depends on my goals, what I have done recently, and how I'm feeling. For all the reasons that the above question is ridiculous, "which training zone is the best?" is equally ridiculous. The purpose of the Training Zones feature is not to create a universal target - the way 100% sleep performance[33] is always worth aiming for - but rather to help you understand how your goals are, or are not, aligned with your training, as well as to help you plan your workout today based on your Recovery this morning and the training effect you are hoping to elicit.

Staying within the Optimal Training Zone allows an athlete to recover from the training stimulus within 24-hours. However, this region is not always the most advantageous. For instance, tapering, in which an athlete dramatically reduces training load in an attempt to reduce fatigue, has been

[29] Cropley et al., 2017
[30] Breslow, 2016
[31] Mah et al., 2011
[32] "Fluids in Sport", 2009
[33] https://www.whoop.com/support-categories/getting-started/#what-is-sleep-performance

shown to produce significant performance improvements[34]. Thus, the Restoring Zone may be the most advantageous zone for an athlete with an upcoming competition. Additionally, significant fitness gains can be achieved by alternating between periods of overreaching and recovery[35,36,37] so spending time in the Overreaching Zone is an important part of many training plans. While time in all 3 zones can be beneficial towards reaching one's goal, over the long term it's important users achieve a balance between training and recovery. This is where the "Optimal Zone" gets its name; users should aim over the long term to average roughly around this middle zone.

THE CAVEAT: IT'S NOT JUST ABOUT THE ZONE

It is important to note that not all Overreaching, Optimal and Restoring days are equal. Clearly, even with the same distribution of Overreaching, Optimal, and Restoring days, a sleep-deprived athlete with unhealthy behaviors that continually wakes up with low Recovery will likely achieve different fitness gains than a well-rested, healthy athlete with consistently high Recovery. To use the WHOOP Training Zones effectively, athletes should strive to wake up as recovered as possible — achieved through behaviors such as adequate sleep, drinking plenty of water, managing stress, and other healthy habits.[38,39,40]

In order to get as fit as possible as quickly as possible, you will need to take on high-Strain workouts. But in order to be ready for those high-Strain workouts, you need to be properly Recovered; so while every Recovery value has corresponding Strain values that will typically cause you to be more, less, or similarly Recovered the next day, not every Recovery value has corresponding Strain values that would typically cause you to be prepared to work hard enough to meet your fitness goals for the day. It is therefore important to strive for as many "green" Recovery days as possible to enable training hard without venturing too far into Overreaching territory.

CONCLUSION

The WHOOP Strap 2.0 and the WHOOP Data Analysis Platform can help remove many of the mysteries of training. By monitoring our physiological response to cardiovascular load and recovery efforts throughout the day, we can take decades-old training philosophy and meaningfully apply it to better reach our goals and true physiological potential.

[34] Turner, 2011
[35] Mujika et al., 2018
[36] Budgett, 1998
[37] Turner, 2011
[38] Cropley et al., 2017
[39] Sepulveda et al., 2014
[40] Cebeci et al., 2015

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