RENAISSANCE RP PERIODIZATION

SCIENCE IS STRONGER

RECOVERING FROM TRAINING

HOW TO MANAGE FATIGUE TO MAXIMIZE PERFORMANCE

Dr. James Hoffmann / Dr. Mike Israetel / Dr. Melissa Davis

About the Authors

Dr. James Hoffmann holds a PhD in Sport Physiology and is a consultant for Renaissance Periodization. He is also the former Program Director of the Exercise and Sport Science program and the women's Rugby team coach at Temple University in Philadelphia, PA. While at Temple, James taught courses in strength and conditioning theory, strength and conditioning practice, exercise physiology, and biochemistry. James earned his PhD under Dr. Mike Stone at ETSU, where he focused on the application of sled pushing to sport performance enhancement in Rugby players. As the team's assistant coach and Head Sport Scientist, James has coached numerous Rugby players at ETSU, where he was also the head strength and conditioning coach and weight room manager. Originally from Chicago, Illinois, James is a lifelong athlete, who has achieved high ranks in competitive Rugby, American Football, and Wrestling, and is currently pursuing Thai boxing.

Dr. Mike Israetel holds a PhD in Sport Physiology, and is currently the head science consultant for Renaissance Periodization. Mike was formerly a professor of Exercise and Sport Science in the School of Public Health at Temple University in Philadelphia, where he taught several courses, including Nutrition for Public Health, Advanced Sports Nutrition and Exercise, and Nutrition and Behavior. He has worked as a consultant on sports nutrition to the U.S. Olympic Training Site in Johnson City, TN, and has been an invited speaker at numerous scientific and performance/health conferences, including nutritional seminars at the U.S. Olympic Training Center in Lake Placid, NY. A co-founder of Renaissance Periodization, Mike has coached numerous athletes and busy professionals in both diet and weight training. Originally from Moscow, Russia, Mike is himself a competitive bodybuilder and professional Brazilian Jiu Jitsu grappler.

Dr. Melissa Davis holds a PhD in Neurobiology and Behavior and is a consultant for Renaissance Periodization. She has 10 years of research experience studying somatosensory based disease intervention, cortical plasticity, and brain development at UC Irvine. Her work has been featured in Scientific American, published in high impact, peer reviewed journals, and recognized by faculty of 1000. Melissa has earned awards for teaching, scholarship, and excellence in research. She also designed and wrote didactic material for the undergraduate Neuroscience lab course at UC Irvine and has been involved in science outreach activities for over a decade. Melissa is currently a Brazilian Jiu Jitsu brown belt under Giva Santana and has earned numerous titles including IBJJF Master World Champion in 2015 and 2016. She also represented the United States for her division in the international Abu Dhabi World Pro Competition in 2015 and 2017.

A special thanks to our editors

Sonia Bramwell holds a BA in Professional Writing from Michigan State, with a focus on technical and digital writing, and has 13 years of experience applying these skills, particularly in the arena of writing for software products. Sonia is currently also a project manager at Renaissance Periodization. **Stephen Dvorak** holds an MFA in Creative Writing from University of Miami and is currently a Research Study Assistant at Northwestern University's Feinberg School of Medicine. Both individuals were indispensable in the editing of this book.

About Renaissance Periodization

Renaissance Periodization is a diet and training consultation company. RP's consultants, including the authors of this book, develop diets and training programs for every kind of client. RP works with athletes who are trying to reach peak performances, business-people that need more energy at work, and others from all walks of life who want to look and feel better. When he founded RP, CEO Nick Shaw had a vision of a company that delivered the absolute highest quality diet and training to its clientele. By hiring almost exclusively competitive athletes who are also PhDs in the sport, nutrition, and biological sciences, and Registered Dieticians, Nick has assembled a team of consultants that is unrivaled in the fitness industry. In addition to training and diet coaching, the RP team also produces self-coaching diet and training templates, publishes numerous books and articles, and produces instructional videos on diet, training, periodization science, and all matters involving body composition and sport. To date, RP has helped over 100,000 people improve their fitness and health, with more success stories accumulating every day.

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Introduction

Training is a vast concept with a broad definition. It applies to all manner of skills and tasks: a virtuoso musician trains their muscle memory for a big performance, a craftsman plies his trade to perfect his work over the years, and an athlete may employ any number of physical techniques to be the best at a sport. As you prepare to train, you likely have a goal in mind, be that practical strength, agility, endurance, or more wins in your chosen sport. No matter what we train for, we all train for the same reason: to get better. Training yields improvement over time; we don't see the benefit of our training instantaneously, nor after each individual training session. In fact, we usually experience *disimprovement* across any given training session. Some of the most productive training sessions leave us the most exhausted. Breaking ourselves down this way sets in motion the gears of improvement. While we do train to improve, getting temporarily worse is a big part of that improvement process.

The improvement process is a cycle of breaking down followed by resting, in order to build back up bigger, better, faster and stronger over time. The cycle starts with working toward fatigue in training, and the recovery process begins as soon as training ends. It's during this recovery period that we actually get better. We adapt our performance systems, we heal, and we reenergize for the next session. Likewise, when we train to learn new tasks and movements, it is during recovery that this new learning is consolidated into long term memory. If you want to perform at your absolute best, your mission is twofold. First, you need to find the most specific, logical, diverse, and productive ways to train. Second, you must find the optimal way to recover from that training. That's what longitudinal performance is all about—finding the most powerful methods for both training *and* recovery. One is nearly pointless without the other, and an imbalance between the two will significantly diminish results.

If you've ever looked into getting some books on how optimize your training, you likely found no shortage of them! Not only are there numerous resources about the general training process, there are individual books about how to train hyper-specifically for each sport and sub-sport. There are books on training for all manner of sports from weightlifting to triathlon to figure skating and everything in between. If you want in-depth knowledge about how to best train, it's just an online order away. Of course, not all of these resources are created equal, so it's always a good idea to check the author's' qualifications and the book's references before undertaking their recommendations.

But what about books on recovery? If recovery is consequential to training, surely there are both general and specific books on it as well. It turns out that this is not the case. While there are lots of books on injury healing, there is a paltry selection of texts on the process of normal recovery from training—the very process responsible for a huge fraction of your gains! Yep, you can read hundreds of pages about most any type of training, but, in the equally important realm of recovery, you're left scrounging around online for the occasional article or scantily-relevant book.

We at Renaissance Periodization want to start to change that with this book, which represents our best thinking on the scientific and practical approaches to recovery from training. This isn't a simplified or novel tour of the subject: chapter by chapter we've delved into the specifics underlying the recovery process, and present you with a synthesized and actionable guide to recovering from your training. Included in this text are detailed discussions of:

- The definition of fatigue accumulation, with descriptions of its causes, consequences, and methods of detection.
- The relationship between training volume landmarks and fatigue management.
- The definition of recovery and a discussion of its many intricacies.
- An illustration of the most effective recovery strategies and the relative magnitude of their effects.
- A detailed description of each of the effective recovery strategies, and tips for how you can apply them to your own process of improvement.
- A description of new and experimental recovery strategies that are currently in development.
- The myths and fads in recovery from training, including a list of the most popular recovery strategies that have been proven ineffective or downright detrimental to recovery and performance improvement.

At the end of the book, we've provided you with a list of resources for further reading, to aid in further understanding the concepts covered in this book. We wrote this book for you: the intelligent, dedicated coaches and athletes who want to train hard and maximize their gains. Rest assured that all assertions herein are firmly rooted in the most current scientific data, making them credible guidelines for optimizing recovery, and thereby overall performance. We all love the training process and are addicted to the grind, but let's be honest—the world of sport is not just about giving your maximum effort—it's as much about reaping the benefits of that effort in the form of seeing ourselves improve at our chosen sport or fitness ability. To arm yourself with key knowledge about the vital role recovery plays in your fitness progress, read on!

1 FATIGUE

Section 1: Defining Fatigue

Before we can talk about the recovery process in-depth, we must determine what it is we're recovering from. Fatigue is defined as extreme tiredness and can describe a broad range of physiological and psychological states of exhaustion. Fatigue can be induced by stress, training, mental workload, illness, or a combination of these. If we intended to understand recovery from training, then we must first have a specific understanding of the fatigue generated by that training. To do so, we will use a less broad, more sport-science-specific, operational definition. In sport science, we define fatigue as:

> *The disruption of physiological systems that leads to a decrement in athletic performance.*

There are two main subtypes of fatigue:

- **Acute Fatigue** is the short-term disruption of systems that leads to a decrement in performance within a given training session and the period immediately following. If you can do 5 pull ups when you're fresh, but can only muster about 2 pull ups at the end of a grueling back session, it's acute fatigue that's responsible for that decline in ability.

- **Cumulative** (or "chronic") **Fatigue** is the disruption of systems that affects future training sessions. So, while acute fatigue is measured in minutes and hours, cumulative fatigue is measured in days and weeks. It's called "cumulative" fatigue because it's really acute fatigue that has never been alleviated. Not all acute fatigue is resolved between training sessions over the course of days or weeks, and the result is an increasingly higher level of fatigue. To use the pull up example with two back sessions a week, you might heal up from the last session only fast enough to be able to do 5 pull ups every week. If you train twice as hard in each session and cannot recover, soon the acute fatigue from each back training session will start to accumulate. The result is that while last week you could do 5 pull ups, this week you might only get 4, and if you keep up this unsustainable volume of training, you could be down to 0 pull ups in a matter of weeks.

If you want to see gains from your training regime, acute fatigue is unavoidable. If you're still able to perform at the same level at the end of a training session as you could at the beginning, the chances that you will improve by your next session are minimal. Training is *supposed* to make you tired, and it's normal to see your performance decline during a session. This idea, although intuitive, is not always appreciated.

Cumulative fatigue requires more careful management, but its underlying processes are essential to gains. The reasons for this are summarized by two training principles: Overload and Stimulus Recovery Adaptation (SRA). The Overload Principle states that in order for training to make you better, it must be disruptive and challenging relative to your existing abilities. The SRA Principle states that once you've recovered to about 90% of full training capacity, you must resume training at a higher intensity in order to maximize accrued gains, which might otherwise be lost waiting for total system recovery. Together, these principles evidence that cumulative fatigue is necessary for adaptation to occur.

Fatigue can also be subdivided into *peripheral* and *systemic fatigue.* Peripheral fatigue is that sustained in the local muscles and tissues of the trained regions. Systemic fatigue refers to the amalgamation of local, central nervous system, and psychological fatigue. Every instance of local fatigue contributes to systemic fatigue, as does life stress, diet, lack of sleep, and so on. Session to session, week to week, fatigue accumulates. During this time training is also making us better. Fitness therefore rises with fatigue throughout training, as shown in Figure 1. Preparedness is used to describe the degree of fitness we are able to express at a given time. Because fatigue will reduce our ability to express fitness, as fatigue rises preparedness eventually drops across a training period, despite increased overall fitness. Prolonged high-order fatigue lowers preparedness so much that overload training becomes impossible. After all, how can you affect a "harder than ever" training ethos if you're too fatigued to train even at the previous week's level? Thus, while some cumulative fatigue is necessary to drive our gains, it must eventually be alleviated if we are to continue to progress.

Figure 1: Interaction of fitness, fatigue, and preparedness across training loads

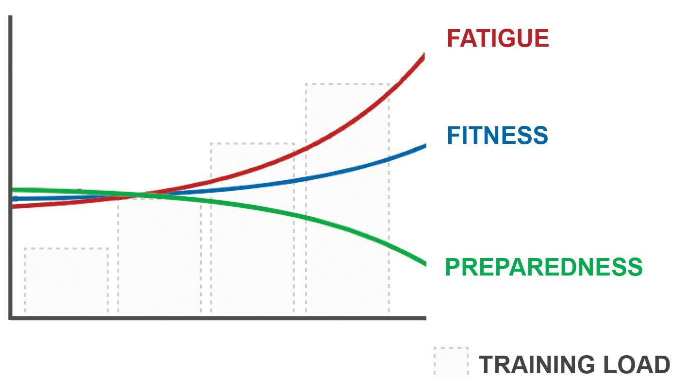


Figure 1. As training load increases over time, an athlete improves, so fitness (blue) rises across increasingly overloading training (dashed, gray bars). Fatigue (red) also accumulates across increasingly difficult training, eventually masking fitness expression and thus reducing preparedness (green). When fatigue gets extremely high and preparedness extremely low, recovery strategies are needed before more overloading training can be attempted, as we will discuss in depth throughout this text.

Now that we've got the basics of fatigue sorted out, let's delve into the exact processes underlying fatigue.

Section 2: The Causes of Fatigue

Some features of training cause more fatigue than others, and interestingly, not all fatigue is generated by training. Some fatigue is accumulated from sources wholly external to the body, such as psychological stressors. Below are some of the primary training and lifestyle variables that have effects on how much fatigue accumulates.

Fatigue-Contributing Training Variables:

- Training Volume
- Training Intensity
- Training Density
- Training Frequency
- Impact/Contact/Direct Disruption

Fatigue-Contributing Lifestyle Stressors:

- Daily Physical Tasks
- Sleep Deprivation
- Poor Nutrition
- Psychological Stressors
- Illness
- Toxin Exposure

Let's go through and define each of these fatigue-contributors and find out how they all add up to the cumulative fatigue that any athlete experiences.

Fatigue-Contributing Training Variables

Training Volume

Training volume is easy to define. It's the total amount of physical work that's done in a training program – and by "work", we mean the physics-based definition of work:

Work = Force x Distance

If you weigh 150 pounds and run a total of 3 miles, your muscles produce a certain amount of force to move your body across that distance. That means you perform a quantifiable amount of work. If you run 6 miles the next day, your workload roughly doubles, and if your 75 pound nephew joins you, his workload would be roughly half of yours. Training volume can be calculated in the absolute sense (in units like Joules or Calories) or in a relative sense (as 75% of your usual cycling distance and so on). Training volume can also be calculated by tracking distances in aerobic work (miles run, biked, or swum), or by counting the product of sets, weights, and reps done in the gym. However you keep track of it, the total workload of a program is a very important contributor to fatigue. In fact, it's probably the most important factor in many cases.

The reason training volume has such an impact on the amount of fatigue you'll experience is related to carbohydrate (glycogen) depletion. Glycogen is the most important endogenous energy source for the work performed during hard training. Higher volumes of training utilize greater amounts of glycogen, leaving the body depleted of this essential energy source and less capable of performing work. Studies have shown a near-linear relationship between work done by athletes during quantified training sessions and glycogen depletion in their muscles. As we'll see in the following paragraphs, workload and intensity of training are often confused. Although intense training can feel like it must be more fatiguing, unless the actual volume of training (work performed) is higher, a less intense but more voluminous session will generally accumulate more fatigue. Let's now take a look at training intensity to get a clear idea of the distinction between these two variables.

Training Intensity

Intensity can be measured as absolute—the amount of force or power produced to do the work, and as relative—the fraction of the individual's output required to do the work. Absolute intensity is calculated using physics, whereas relative intensity is calculated as relative to the capacity of the individual producing the force or effort. A quick and easy way to make sense of this is to imagine someone squatting 150 lbs. The force required to move that weight across a certain distance at a certain velocity is an absolute measure of intensity, and remains constant irrespective of who is doing the squatting. The relative intensity of a 150 lb squat on the other hand will vary based on the individuals doing the squatting. Six sets of ten squats at 150 lbs would be of low intensity for someone with a one rep squat max of 500 lbs, and not very fatiguing at all. In contrast, for someone with a 200 lb max squat, six sets of ten squats at 150 lbs would be substantially more fatiguing, due to the much higher relative intensity. Keep in mind, although we use a weight training example here for simplicity, intensity refers to force or power output in sprints, jumps, punches, and so on. Any training that requires force or power can be measured with the parameter of intensity.

To give an inter-exercise example, if you walk 4 miles, your quads produced enough contractile force with each step to be equivalent to squatting approximately 15% of your one repetition maximum (1RM) for lifting. Since the volume is so high, we can count the 4 mile trek in "numbers of squats done" (even if we adjust for the partial range of motion of the quads during the normal walking stride versus a full squat, 4 miles would still be equivalent to hundreds of squats). Let's say that 4 miles of walking is the equivalent workload of about 120 body weight squats. That's a whole lot of squatting, but you don't feel completely exhausted from a 4 mile walk in the woods. The reason for this phenomenon is that the intensity of this hiking workout is very low. Strong transient forces simply don't occur, and therefore not much structural damage (fatigue) is accumulated.

Let's take another example with a more intense load. If you weigh 150 pounds, 120 body weight squats is the equivalent of 60 150 lb weighted squats. In the latter case, you only need to do half the number of squats to accumulate equivalent fatigue, since you have doubled the weight being lifted. If you weigh 150 lbs, that means 6 sets of 10 squats at 150 lbs. That kind of session will result in a disproportionately high amount of fatigue compared to walking 4 miles, even though the volume is about the same. This difference in fatigue production is due to the large increase in intensity.

Let's take it one step further to illustrate the point. Say your one rep squat max in this example is 250 lbs. In that case, 6x10 at 150 lbs will be very fatiguing, but it doesn't compare to the fatigue from squatting 240 lbs for 37 single repetitions—a volume-equivalent load. The fatigue caused by even 10 singles at 240 lbs would be about the same as 60 reps at 150 lbs, because intensity is such a big contributor to fatigue. In addition to exponentially greater fatigue, the damage to muscle and connective tissues would eventually be counterproductive. Thus, volume-loads are not comparable with a 1:1 ratio. Rather, volume-load intensity must always be factored in, so as to accurately predict fatigue outcomes.

Let's talk a little more about how the volume-intensity relationship contributes to fatigue under different volume distributions, resulting in different relative intensities across sets. For example, if your max squat is 250 lbs and your best set of 10 is 175lbs, doing 6 sets of 10 at 150 may never push you very hard in any one set. Now, if we had you use the same 150 lbs, but go to concentric muscular failure each time (where you could no longer stand up with the bar and spotters had to catch you at the end of each set), your reps to 60 total might look something like:

Set 1: 15 reps
Set 2: 11 reps
Set 3: 10 reps
Set 4: 9 reps
Set 5: 8 reps
Set 6: 7 reps

The same work is performed—60 total reps (volume) using the same 150 lbs (absolute intensity). Despite matched volume and absolute intensity, this training session is going to produce more fatigue than the 6x10 session—not by a massive amount, but still meaningfully more. When systems are repeatedly brought close to their limits, they take more damage, even at the same total volumes and absolute intensities. The closer they are brought to these limits, the more fatigue will be generated, and this increase will be exponential. What does the exponential part mean? It means that if you did the 60 total reps and stopped 8 reps short of failure on each set (doing something like 6 reps each set), the difference in fatigue would not be much greater than if you stopped 6 or even 4 reps shy of failure on each set. At 3 reps shy of failure, however, each set would start to contribute a disproportionate amount of disruption to the physiological systems, much more at 2 reps shy of failure, with the biggest increase in fatigue between each set 1 rep from failure and going to total concentric failure on each set. This is illustrated by Figure 2 below.

Figure 2: Fatigue increases across training intensities

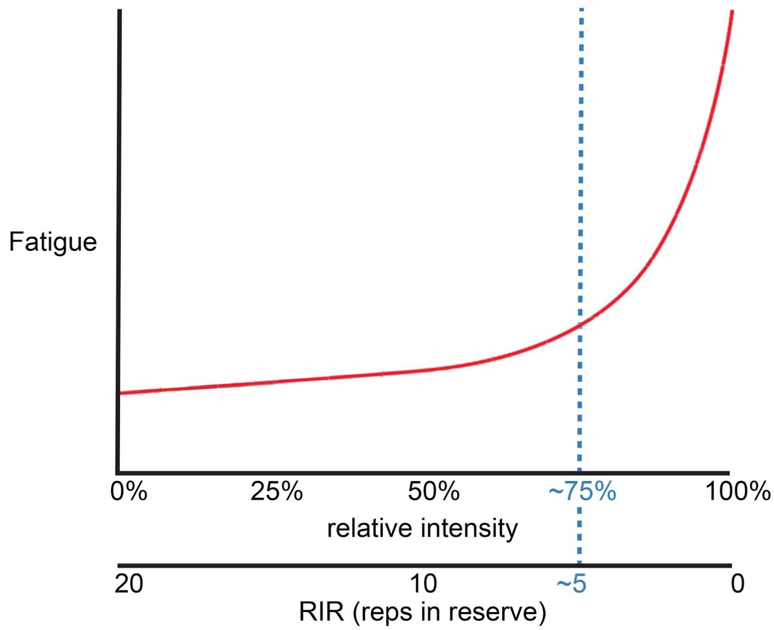


Figure 2: Fatigue (y-axis, red line) rises exponentially as relative intensity increases (x-axis). Fatigue increases slowly at relative intensities below 75% of the athlete's maximum (blue dashed line). This 75% threshold is equivalent to ending a set in lifting at five repetitions from failure. Irrespective of absolute intensity, pushing to 75% of capacity or to five reps from failure is the approximate point at which the athlete's fatigue begins to rise steeply.

In short, the closer you push your training to maximal effort (or muscular failure in the case of weight training), the more fatigue you will accrue, irrespective of total volume and absolute intensities. This higher level of fatigue results from both the physiological and psychological effects of pushing one's body to its limits.

Training Density

Training density can be defined as the volume of training performed over a given time span. Increasing volume, decreasing training duration, or a combination of these increase training density.

All other factors being equal, sessions and programs with higher densities cause higher levels of fatigue. One of the primary reasons for this is that metabolic byproducts that accumulate during training are shuttled away from working muscles during rest periods between sets. Increased density of training means less rest and more training in a given training session, which in turn means a shorter time window for these byproducts to be removed. These remaining metabolites invoke the soreness experienced after training and also contribute to further inflammation of the local tissues, adding to fatigue. Overall volume (how much training is being done) and intensity (how hard the training is) have the largest impact on fatigue. When training volume and intensity are held equal, increases or decreases in training density alone have a relatively low, but measurable, impact on fatigue.

Training Frequency

Training frequency is how often you might train, usually measured in sessions per week. For example, if you train lower body on every Monday and Thursday, your lower body training frequency is 2x per week. Training frequency by itself doesn't have a significant effect on fatigue in the absence of volume increases. If frequency changes, but total weekly volume stays the same, then there will be no significant increase in fatigue. For example, 16 sets of squats in one day, or 8 sets per day over two days, or 4 sets per day over four days would all generate a similar amount of fatigue (differing minutely only as a result of training density). Thus, for the most part, alterations in training frequency only need be taken into account if the volume is changed.

One minor but noteworthy way in which frequency can alter fatigue has to do with training distribution across a week. When intense training is distributed evenly throughout the week, one can better recover from acute fatigue generated at each session, and therefore achieve more maximal output on average. For instance, say your goal is to do 15 sets of 10 squats per week, where each set is 2 reps shy of failure. If you try to do all 150 squats in one session, you'd have to drop the weight used in order to accommodate the reps without going to complete failure so you can finish all of the sets in a row. If instead you split the work into 5 sets each on Monday, Wednesday, and Friday, you'd be fresh for every training session, and would be able to use more weight. The good news is that using the latter strategy, you would achieve a much higher intensity of work, and therefore generate a better overload. The downside is that the higher intensity average would lead to more fatigue, and thus the need for greater recovery efforts.

Internal and External Tissue Damage

One of the most important causes of fatigue is the breaking and tearing of the body's tissues. Internal structural damage is caused by the pressure of internal forces on bones, muscles, and connective tissues during exercise. The degree of damage incurred from these forces varies based on volume and intensity of training (affectors of fatigue discussed earlier). The type of muscle contraction also has an effect: loaded eccentric contractions tend to generate more damage than concentric, but most real world exercises require both types of movement.

Breaks, tears, and other trauma can also be generated externally via contact and impact with the environment around you. The type of activity performed will determine the degree of direct damage from external impact. For instance, during cycling, you experience almost no impact, because the bike absorbs much of the shock of the road. Walking results in slightly more impact, due to the concussive forces of your feet hitting the ground. Jogging generates even more trauma, due to higher speeds and thus forces, and sprinting causes the most damage of all locomotive activity. Jumping and other explosive activity (with hard landings) exceeds even sprinting, making plyometric training one of the most damaging and therefore fatiguing.

Impact can also be sustained by interacting physically with other people in contact sports. Takedowns and falls in grappling, slides in soccer, and tackles in football or rugby all cause physical damage, and cause fatigue to accumulate, even if no macro-level injuries result. Thus, such sports are more fatiguing per unit volume than those that have no contact component. This is necessary to consider in the grand-scheme of program design.

Fatigue-Contributing Lifestyle Stressors

Daily Physical Tasks

While fatigue is caused largely by the training process, other aspects of the athlete's life unrelated to training also contribute to fatigue. Walking around, lifting objects and putting them back down, getting up and down from the couch or desk, cleaning the house, taking the stairs, walking the dog, etc. all have a metabolic cost, and thus contribute to fatigue in a meaningful way.

In an ideal world, athletes would spend almost every second of their waking lives either training or in near-total relaxation: training to produce gains, and relaxation to promote recovery and eliminate additional fatigue from non-training physical activity. A typical day in this athlete utopia might look like this: Wake up and eat breakfast in the morning, then sit and read calmly for an hour, get in a hard two hour training session, have a post-training meal, and then spend the afternoon lounging poolside before getting in another two hour early evening training session, followed by an evening of eating and relaxing on the couch with friends and a good night's sleep.

This ideal world described is unattainable for most of us, as, here in the real world, we're faced with the daily grind of commutes, work, housekeeping chores and social obligations, not to mention child rearing or other caretaking duties for some, tending to all of which results in differing levels of daily physical activity outside of training. As work goes, where most of us spend a significant chunk of our week, while some jobs are relatively sedentary, others may entail substantial physical labor, causing those with the latter kind to accumulate a significant amount of fatigue from their non-training related daily activity. Likewise, a woman living in a big house on 2 acres of land with a couple of horses and a dog will have a lot more physical demands to meet each day than one living in a condo with her husband and no pets, where the grounds are tended to for them, there are no animals to feed, lug bales of hay for, clean after or walk, and the couple can divide and conquer their household chores.

As such, fatigue from daily tasks should be considered in the design of training programs. In some cases it can be one of the most important factors – if you work in construction five days per week, the toll of lifting, carrying, and wielding heavy tools and machinery may limit the amount of productive training you can fit into a given week. While we'll cover this in much greater depth in later discussions, the most straightforward way to measure the magnitude of daily tasks is by the number of calories that they consume. Let's say you just started a new, more physically-demanding job, and find that you have to eat 1000 more calories per day just to maintain your weight. That's 1000 calories per day of added fatigue-generating energy output, and counts as low-intensity training in and of itself. Without adjustments to the rest of your program, such an increase in energy consumption can have serious negative consequences. It's important that you avoid ignoring these seemingly minor changes.

Sleep Deprivation

Lack of sleep can be a major contributor to the accumulation of fatigue. Sleep plays an important role in regulating tissue regeneration, memory consolidation, immune function, and is an anabolic switch for virtually all body systems. Although the dosage of sleep required can vary from person to person, inadequate sleep is clearly associated with a variety of physical and cognitive impairments, ranging from acute performance decreases to chronic overstress and overtraining syndrome.

Achieving an ideal dose of sleep every night is easier said than done, and often times we can shrug off one or two restless nights per week. Sleep is, however, one of the most powerful alleviators of fatigue from *all sources*—so those one or two bad nights that we easily dismiss could become a serious detriment in the following weeks as systemic fatigue starts building up. Lack of sufficient sleep will quickly start manifesting itself in performance decrements, mood disturbances, reduced training capacity, illness, and eventually can lead to non-functional overreaching and overtraining syndrome.

Poor Nutrition

One of the more intuitive contributors to fatigue is simply running out of energy, specifically chemical energy that we derive from food. Insufficient daily caloric and carbohydrate intake or dehydration can all hinder performance and recovery ability. Daily calories provide us the raw energy needed to sustain daily life, not to mention the rigors of training. When an athlete is under hypocaloric conditions, or in an energy deficient state, they will begin breaking down their endogenous energy stores to sustain their energy needs. This process triggers a series of catabolic processes used to break down biomolecules for energy, which is great for someone trying to lose weight, but directly impedes anabolism and recovery.

Similarly, if those calories contain an insufficient proportion of carbohydrates, fatigue will also increase. Carbohydrate is the primary energy substrate for virtually all sporting and exercise activities and is directly related to the workload of exercise that can be performed. This essentially means that the more (training) work you do, the more carbohydrate is needed to fuel that work. If carbohydrate intake is inadequately matched to the athlete's daily workload, the limited endogenous glycogen stores can become functionally exhausted. Low muscle glycogen is not only associated with fatigue, but can also perpetuate increases in catabolic activity.

Dehydration can result from a variety of factors and can lead to significant physiological stress. Though many of us often dismiss dehydration as a concern on the basis of feeling in touch with our body's hydration needs, many athletes are chronically dehydrated and potentially unaware of the consequences. The effects of dehydration can range from dry mouth and thirst all the way up to delirium, seizures, heat illness, and death. As little as 1-2% body weight loss due to dehydration can lead to decrements in performance, so maintaining a euhydrated state is a simple way to manage fatigue.

Psychological Stressors

One of the most interesting discoveries in the study of fatigue is that all stressors are physically cumulative, including emotional and psychological stressors. This means that emotionally taxing events in your life can directly impact your training. You might find yourself performing poorly in athletic endeavors during finals week, having your lift go terribly the week a long term relationship ends, or having a subpar training session after getting snapped at by your boss at the end of a long day at work.

All of this means that the more calm and happy you are, the less fatigued you will be and the better you will manage existing fatigue. Conversely, the more psychological stress you carry the more negatively affected your training process will be. In our earlier discussion of relative intensity, we mentioned that higher relative intensities are both physically and mentally fatiguing. This is because hard training is psychologically difficult. Pushing your body involves pain, and driving yourself to endure this pain, even though we have healthful outcomes in mind, requires mental energy, and invokes psychologically stressful thought processes. The higher the relative intensities, the more pronounced these thought patterns become, so much so that you could be under psychological stress for days before a PR attempt in a big lift or a competition. When deciding how high a relative intensity to employ in your program, remember to account for psychological factors in addition to physical ones.

Illness

Recovering from illness takes the coordination of many body systems. Your body prioritizes this type of recovery above training recovery (and for good reason), so that when you're sick, your fatigue levels will be much greater. This is in part because the body's primary recovery systems will be busy attending to the illness and not your training-induced fatigue. The sicker you are, the worse the fatigue will be. You can train through a head cold, but when you have the flu, fatigue is so high that getting out of bed and using the bathroom might be your most challenging workout for the day.

Fatigue from training and illness interact in other ways as well. As mentioned, when you're sick, your total fatigue is very high, and this can limit your ability to train productively. Training while sick can not only reduce your ability to recover from training, but also substantially impede your recovery from the illness. Importantly, if you train too close to or over your limits of recovery for a prolonged amount of time, your chances of getting sick in the first place also increase dramatically.

Alcohol and Other Drugs

Various toxins can add to fatigue by demanding effort of body systems normally used to heal fatigue for detoxification. Toxins such as alcohol directly interfere with physiological systems. Alcohol consumption exponentially increases fatigue, a drink or two per day adds almost no fatigue, but four to six drinks per day adds a considerable amount of fatigue, and getting blacked-out drunk can cause devastating levels of fatigue (never mind endanger the athlete's life). The dose-response of fatigue to the introduction of toxins to the physiological system is important to consider when addressing lifestyle choices in the scheme of managing recovery.

Next, we delve into the exact mechanisms of fatigue accumulation at the nervous, muscular, and hormonal levels.

Section 3: The Pathways of Fatigue

As aforementioned, fatigue can be separated into acute fatigue, which dissipates within a single training session or very shortly thereafter, and cumulative fatigue which can take days, weeks or longer to resolve. For our current purposes, recovery from the latter type of fatigue (though not from the former) is critical, so we will go briefly over the acute pathways of fatigue and focus more heavily on potential pathways for its accumulation.

Acute Fatigue Pathways:

- ATP Depletion
- Creatine Phosphate Depletion
- Nervous System Disruption
- Oxygen Depletion
- Blood Sugar Depletion
- Metabolite Summation

ATP Depletion

Adenosine triphosphate (or ATP) is the transporter of chemical energy within cells and therefore the rate-limiting aspect of energy output. Insufficient ATP generates acute fatigue in high intensity exertions. The average muscle cell only stores enough ATP for about 1 second of maximum force production (explaining why plyometric movements are so depleting). Consequently, stored ATP is quickly exhausted during the first few seconds of exercise, forcing the body to regenerate ATP through the breakdown of other energy substrates.

Creatine Phosphate Depletion

When ATP is broken down into adenosine diphosphate (ADP) and inorganic phosphate as energy is used in the muscles, creatine phosphate (CP) can rapidly replenish ATP by donating its phosphate group to adenosine diphosphate (ADP). While this process doesn't quite fully restore ATP levels, it comes close, and there is enough CP in the average skeletal muscle cell to power around 10 seconds of near-maximum muscle contractions. This is why 100 meter sprinters can run about the same speed toward the end of the race as they did about one quarter of the way through: not quite as fast as they did at the start, but pretty close.

Creatine phosphate is depleted during high-intensity efforts, and needs several minutes to recover to complete or near-complete levels. This is the reason that taking a 1-3 minute rests between sets in weight training is a good idea. CP is regenerated to its full capacity within about 5 minutes of rest, which makes it a valuable energy substrate during intermittent, high intensity efforts.

Nervous System Disruption

It is generally accepted that decreased motor neuron output resulting from prolonged or intense exertion plays a role in fatigue generation, but the exact mechanisms remain unclear. Contributing factors may include negative feedback mechanisms via inhibitory neurons in the spinal cord, decreased or disorganized signaling from the motor cortex in the brain, and local neuronal firing issues (though these likely originate with biochemical changes in the muscle fibers that affect neuron signal propagation).

These acute nervous system effects curb performance within the session, but sufficient rest should restore them to normal states.

Oxygen Depletion

Oxygen consumption in the muscle tissue can get so extreme that it exceeds the rate at which the body can deliver fresh oxygen to that area. In exercise physiology this is termed the "Oxygen Deficit", where the oxygen already present in the muscle tissue is metabolized rapidly during exercise, but the cardiovascular and pulmonary systems have not yet adjusted to the increased energy demand on the body. This creates a "deficit" or gradient of oxygen concentration between the muscle tissue and the bloodstream. Within a few minutes of rest, however, oxygen levels can be replenished and homeostasis restored.

Blood Sugar Depletion

When we consume carbohydrates, whether as complex carbs from bread and pasta or as simple sugars from candy or juice, they are broken down into simple glucose molecules and released into our bloodstream to be used or stored for later. If you train for long enough without eating, especially under low carbohydrate conditions, you can run short on blood sugar. Because the nervous system prefers blood glucose over any other kind of fuel, when this preferred energy source is low, physical performance levels will begin to predictably drop. The good news is that a simple carb shake can quickly remedy this. Unused blood glucose can be combined into huge polysaccharides composed of many glucose molecules, called glycogen and stored in the liver or muscles. The liver releases its stored glycogen to replenish blood glucose levels. Even if liver stores are totally depleted, a couple of high carbohydrate meals after training can fully restock this supply. When liver glycogen stores are full, they can provide adequate blood glucose to fuel the demands of hours of training. Muscles also store carbohydrate as glycogen, but use it as a local energy source within the muscle rather than releasing it into the bloodstream. Due to its location within active muscles in need of energy, muscle glycogen is used preferentially during exercise and is more rapidly depleted.

Metabolite Summation

Muscles use a variety of reactions to produce the energy needed for contraction and these processes come with the creation of byproducts called metabolites. These molecules, including hydrogen ions, CO_2, inorganic phosphate, and lactate are not all innocent bystanders. The accumulation of high levels of metabolites can result in interference with neuromuscular signaling and the mechanisms of muscle contraction itself. Metabolites can also significantly lower local pH, which results in the familiar "burn" experienced during training. Luckily, most of these metabolites are cleared within seconds after training. The notion that lactic acid from a previous day's training remains uncleared from the body for an extended period of time is a common misconception, as lactate concentrations typically return to resting conditions within a few hours after exercise.

While the aforementioned pathways don't accumulate over a period of days or weeks, other pathways do. It's these latter pathways that cause the kind of fatigue that can eventually interfere with results, and it's these pathways that the study of recovery from training seeks to address.

Potentially Cumulative Pathways:

- Glycogen Depletion
- Nervous System Disruption
- Autocrine, Paracrine and Endocrine Disruption
- Psychological Stress
- Tissue Microtrauma

Glycogen Depletion

While the liver's supply of glycogen is mainly used to regulate blood glucose levels, glycogen stored in the muscle is used to power high-intensity, repeated muscular contractions. Because muscle glycogen is such a universally important fuel for athletic performance, its levels in the muscle set the upper bounds for the intensity and volume of sport performance. High levels of muscle glycogen yield the best performances, and everything lower than about half of the normal load result in serious decrements.

In order for glycogen to sufficiently replenish from one training session to the next, carbohydrates must be consumed between sessions. For folks who train at the lower end of the volume spectrum, as much as a gram of carbohydrate per pound of body weight per day of carbohydrate can replace glycogen fully. For those training harder, up to two grams are required, and for those who train with extremely high volumes (pushing four hours of hard training per day), more than three grams of carbohydrate per pound of body weight may be needed per day to keep glycogen levels relatively full. Taking in carbs at the right times and consuming the right kinds of carbs can help maintain glycogen levels to support training and prevent excessive fatigue. Consuming a majority of one's daily carbs directly after training (especially if multiple daily training sessions are planned) as well as eating high glycemic carbs will best maintain glycogen stores.

Maintaining high glycogen levels has an additional benefit: it allows for better anabolic signaling to promote muscle growth. Not only can you train more, your potential results from that training are enhanced as well.

Numerous research findings have confirmed that excessive muscular damage reduces the muscle's ability to take up glucose and assemble it into glycogen. As we train, microscopic damage to the muscle tissue occurs. The more damage occurs, the more our ability to replace glycogen is hindered. This means that for those who train extremely hard and already have trouble getting in enough carbohydrate to replenish glycogen, advanced replenishment strategies may need to be adopted in order to support recovery and maintain performance.

As training volumes and intensities go up, even a diet with adequate carbohydrate intake may not facilitate full glycogen replenishment after each session. Eventually, glycogen levels may be diminished enough to impact performance and the recovery-adaptive processes. Low glycogen levels are strongly correlated to perceived exertion, which means that when your glycogen levels are very low, you feel empty, weak, and slow. If levels become extremely low, full replenishment might take several days of carbohydrate intake with reduced training. Managing muscle glycogen levels is critical for any good recovery strategy.

Nervous System Disruption

Sustained fatigue can prevent the recovery of normal neuromuscular function, which may play a role in inhibiting an athlete's ability to learn new techniques, or even cleanly execute known techniques. Again, this may be a result of cortical or "top-down" fatigue effects, or local neuronal firing disruptions. Irrespective of the source of the problem, performance and progress are halted when nervous system fatigue is not alleviated.

Most nervous system fatigue generated by exercise consists of peripheral effects, but, under chronic conditions, central fatigue can also become an issue. Central nervous system fatigue effects are thought to involve changes in neurotransmitter concentrations in the brain and spinal cord that affect, among other things, performance and perceived effort.

One thing to note is that what we're describing here are temporary fatigue related disruptions, and not disease states or irreversible damage. "Adrenal fatigue" is a diagnosis commonly handed out by under-qualified health field workers. This diagnosis is *not* medically recognized and has in fact been thoroughly debunked in a review of over 3000 research studies entitled *Adrenal fatigue does not exist: a systematic review.* Nervous system changes due to fatigue in most cases are reversible, and do not involve the failure of any glands or systems, but are rather characterized by suboptimal functioning that can be alleviated with rest.

Autocrine Paracrine and Endocrine Disruption

Autocrine, paracrine, and endocrine systems all facilitate intercellular communication in the body. Autocrine signaling involves messages sent from a cell back to itself, leading to changes in other parts of that same cell. Paracrine signaling involves communication between cells in close proximity to each other, and endocrine signaling allows very long distance cell to cell communications using hormones transferred via the circulatory system.

The mTOR/AMPK signaling complex is an example of an autocrine messenger pathway within the muscle cell. (For those interested, the acronyms are short for 'mammalian target of rapamycin' and '5' adenosine monophosphate-activated protein kinase'). The mTOR pathway signals various parts of the cell to begin growing muscle and taking other steps towards recovery and adaptation when the muscle is presented with certain stimuli. These stimuli include tension, stretching under load, the presence of certain metabolites, and high energy availability (resulting from large caloric intake). In contrast, AMPK signals for muscles to cease building and repairing and can even facilitate the breakdown of muscle tissue for extra fuel. The stimuli that upregulate AMPK—and hence prevent muscle growth and may lead to muscle loss—include long duration aerobic exercise, chronic stress, and low energy availability (resulting from low calorie dieting). Various paracrine factors, including growth factors and small signaling proteins like cytokines, also contribute to complex cascades involved in tissue growth, tissue repair, and inflammation. Chronic fatigue can lead to excessive inflammation and slower recovery via this signaling. Please note that mTOR and AMPK are not the only intracellular modulators of fatigue. There are many others, and we simply use mTOR and AMPK because they are well-studied and important to fatigue dynamics.

Endocrine signaling plays a large role in regulating training adaptation and recovery. One of the best known players is testosterone. Secreted testosterone promotes the recovery and growth of muscle cells. Beyond its role in development during puberty, testosterone secretion in adults is stimulated by overload training, and can affect both the muscle tissue and the neurons that innervate it. Changes in testosterone concentration within the body can indicate a significant shift in the anabolic state of the athlete, and, along with other hormones such cortisol, is a valuable marker of preparedness. Testosterone’s effects on anabolism are profound and well documented, which is why many athletes turn to anabolic steroids (analogues of testosterone) to help promote recovery and increase their training loads.

Cortisol is a primary catabolic hormone and is released as part of our normal stress responses. Physical stressors such as training as well as psychological stress stimulate cortisol release. Although cortisol is often cast in a negative light due to its detrimental effects under conditions of chronic stress, it plays an essential role in the breakdown of biomolecules for ATP resynthesis, which provides the energy needed during hard training. This function is extremely useful when energy demands are high. Unfortunately cortisol is not picky about what molecules it's willing to break down for energy. Although protein is not a preferred fuel source, elevations in cortisol can lead to the breakdown of muscle tissue for energy. So, while cortisol concentrations play a necessary role in stress response, their elevations in will directly delay or blunt recovery processes.

Just as testosterone can serve as an indicator of anabolic activity, cortisol can be used as an indicator of catabolic activity. In fact, the ratio of testosterone to cortisol, often referred to as the T:C ratio, is used to measure endocrine balance in athlete monitoring. When testosterone is elevated and cortisol is relatively low, the athlete is in an anabolic state. By contrast, when testosterone is relatively low and cortisol is elevated, the athlete is in a stressed or fatigued, catabolic state.

Although testosterone and cortisol are often the highlighted hormones in our discussions on recovery and fatigue management, insulin also plays a vital role in promoting recovery and adaptation. Insulin is a powerful anabolic hormone, responsible for facilitating glucose and amino acid uptake in muscle tissue. Insulin secretion is stimulated primarily through carbohydrate ingestion, but protein ingestion can also signal its release to a lesser extent. Insulin sensitivity of the muscle tissue is heightened by muscle contraction and can remain elevated for several hours post-exercise. Thus, insulin enhances glycogen replenishment, and therefore the growth and repair of the damaged muscle tissue, making it a valuable hormone to consider for recovery and nutritional strategies.

During day to day functions, these cellular signaling systems work seamlessly to promote performance, recovery, and homeostasis. When overload is presented for consecutive weeks, predictable changes in the function of these messengers manifest. For example, with repeated overloads, mTOR signaling begins to decline and AMPK signaling becomes predominant. This means that while your training sessions may still be going well, muscle growth may reduce and eventually cease if the accumulated fatigue is not resolved. Various paracrine pathways also begin to decline in their promotion of muscle growth and recovery. Endocrine effects are perhaps the most impactful. In an observation first made more than half a century ago, within weeks, continuous overload training reduces testosterone levels and increases cortisol levels. In this scenario, hormones that increase fatigue are going up and the hormones that promote recovery are going down. Mitigating this trend is a critical aspect of any recovery strategy.

Psychological Stress

In both a direct and indirect way, fatigue can take on a purely psychological manifestation. The psychological disposition of an athlete can change with time and have an effect on fatigue. Sometimes the inability to perform overloading training is psychologically based. All athletes are human beings, and we get frustrated, overwhelmed, and bored. Training that is overloading and long in duration (usually weeks and months) without any big variation or break will become overwhelming and increasingly unappealing. If you feel like you can't keep up the pace, have run out of steam for training hard, or have become demotivated to maintain and improve your performance, it is unlikely that you will be able to train at the level required for continued progress. Not only can psychological stress of this nature cause physiological disruption (such as decreases in testosterone and increases in cortisol levels) but can also lead to further rises in psychological fatigue, creating a snowball effect. The psychological pathways of fatigue have to be addressed by any recovery plan. Like physiological fatigue, if psychological fatigue levels are allowed to rise to extremes, they may take upwards of months to wrangle back to baseline completely.

Tissue Microtrauma

Tissue microtrauma describes the process by which hard training damages and breaks down muscle fibers and connective tissue. In order for this type of fatigue to be alleviated, the damage must be allowed to heal. Different structures take on different degrees of damage and have different healing times. Muscle tissue tends to take on the most damage with training, but recovers the quickest (generally within about a week) under normal circumstances. The fascia and tendons incur a lot of damage during intense training, but, because of poorer blood supply and different design, take longer (weeks or more) to heal. Ligaments and bones are the most resistant to damage, but take the longest to heal when traumatized. Training must temporarily cease and, upon resuming, training intensities must remain reduced for consecutive weeks to allow the microtrauma to ligaments and bones to heal completely.

We can now assert that any recovery strategy must accomplish some or all of the following:

- Restore glycogen and other substrates
- Facilitate the recovery of normal nervous system function
- Reestablish normal balances of autocrine, paracrine, and endocrine signaling
- Heal microtrauma in all structures and tissues
- Recuperate the athlete's psychological state

Section 4: Fatigue's Effects on Sport Performance

As you may remember from earlier, cumulative fatigue lasts across training sessions and summates over a month of normal training. In a properly overloading program, cumulative fatigue slowly rises each week, until it reaches levels high enough to encumber performance. At this point, the athlete has entered into a very specific state of physiology called *overreaching*.

Overreaching describes a state wherein the accumulation of fatigue is such that overload training is no longer sustainable. If overreaching is sustained for a very short time, one can continue to train productively. And, if this brief overreach is followed by a period of reduced training, it allows for high levels of adaptation (supercompensation). This is called *functional overreaching.*

In other words, functional overreaching is when the athlete pushes his or her body and mind to just outside the limits of sustainability for a brief amount of time. This push beyond what's normally programmed is a special form of overloading. If functional overreaching is executed properly (not taken too far), a return to normal fatigue levels right after often causes a compensatory effect whereby multiple physiological systems facilitate a greater increase in fitness than normally possible. Functional overreaching is an indispensable training strategy especially to the advanced athlete (for whom gains come harder and more slowly).

Non-functional overreaching describes the unplanned and unwelcome state in which fatigue prevents overload training. One way to prevent functional overreaching from becoming non-functional is to stop pushing when the fitness characteristics you are training for begin to rapidly fall off, or simply put, when you cease being able to train (overload) for these desired characteristics. The longer you stay in an overreached state, the more your physical capabilities will deteriorate. Small fitness deteriorations across training are normal and will not prevent productive overload training, but pushing too far will inhibit gains. If you continue to train too long after desired fitness characteristics have fallen drastically, the most you can hope for is a return to normal abilities, even after fatigue is alleviated. Intelligently pushing your training just over the edge of what you can sustain is an effective strategy, but carelessly and or chronically pushing too far will yield little or no result for all that hard work.

Below is a graphical summary of the duration of overreach that leads to the degradation of various technical and fitness characteristics.

Figure 3: Time course of detrimental fatigue effects

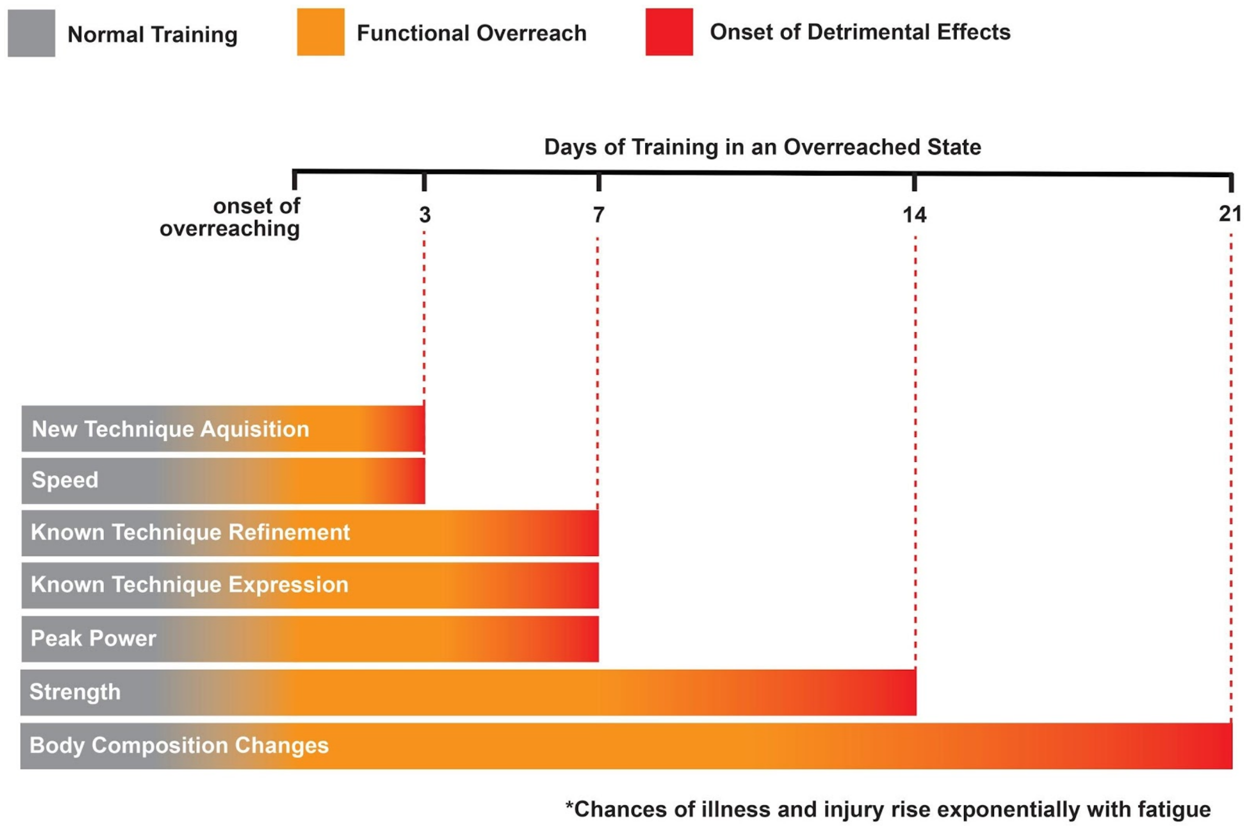


Figure 3: Different fitness characteristics can withstand different durations of overtraining. Once overreaching has begun (represented by bar color transitioning from gray to orange), the time before continued training becomes detrimental (bar transitioning from orange to red) is limited. Three days into overreaching, fatigue levels begin to impede the acquisition of new techniques and speed abilities. By day seven of overreaching, peak power is affected along with the ability to express and refine known techniques. Strength can withstand up to two weeks of overreaching, and it is not until about three weeks into overreaching that body composition begins to be threatened by fatigue levels. Across any overreaching phase, the chances of illness and injury also rise exponentially.

New Technique Acquisition

When athletes are training in an overreached state, they often lose the capacity to acquire new techniques. This means that if you're trying to learn new sport or training skills, a low-fatigue environment is optimal. Even at the very beginning stages of overreaching (after just a few days), your ability to learn new moves and integrate them is compromised. This is one of several reasons that learning new techniques at the end of practice is not ideal. Athletes in technique-heavy sports should schedule new technique and skill acquisition during non-overreaching periods.

Speed

Our ability to achieve maximal movement speeds begins to decline at around the same time as our capacity to learn new technique. This means that after a few days of high fatigue, short distance sprint speed, striking speed, and reactive quickness (side to side movements on a field, for example) begin to decline. For those who track their training with equipment that detects speed, this phase of overreaching can be reliably measured for athlete monitoring purposes. These data can potentially provide early evidence of fatigue and help the athlete avoid pushing too hard for too long and consequently reaping less progress. That in combination with other indices could help guide coaches and athletes as to which potential modifications to training are warranted, when deloads or light days are needed, and so on.

Known Technique Refinement

The ability to refine and improve known techniques is as significant as learning the techniques themselves. Smoothing out the stroke on a forehand tennis swing, polishing the precision of a soccer penalty kick, and improving your catch position in the clean are all examples of refining already learned techniques. In a highly fatigued state, days after new technique expression and speed begin to suffer, the ability to perfect an already learned technique will decline as well. This means that while you can do some very short-term overreaching and still train technique refinement, the time cap on this will still be relatively short. If you're so overreached as to be unable to refine your technique, make sure that your training is focused on power, strength, or other characteristics not yet substantially affected by your current fatigue (see Figure 3 above for some examples).

Known Technique Expression

Eventually, fatigue can diminish your ability to execute moves you know extremely well. About a week into overreaching, most of your known technique expression starts to degrade. At this point, the value of further practice starts to diminish–-if you cannot even execute your most practiced techniques, getting better at them through continued training is impossible. Another problem with this for many sports is that basic learned techniques are prerequisites for advanced tactical training. If you are an overly fatigued rugby player who is having trouble passing and catching the ball, practice of offensive formations that require both of these skills will also be impacted.

Athletes who are too fatigued to express techniques well at the correct speed will often revert to slowing down in order to get the technique right, which allows them to execute the move, but at a great cost: they are now actually *learning to do the technique more slowly*. Well informed coaches know that if you're not practicing correctly, you're not learning correctly.

Athletes in skill based sports can still benefit from functional overreaching, but must be more strategic in its application. A well-structured training plan should have dedicated periods for learning and refining sport and training techniques, and also dedicated time for practicing their expression in the sport setting. For a boxer this would mean a period for learning a new punch combination, and a period for integrating that combo into high speed live sparring.

One strategy to allow for new technique training while still overreaching for other fitness characteristics is to separate technique heavy periods from other training (such as strength and power training). Another option is to minimize overreaching periods, so that there is less interference with technique acquisition. In practice, while strongmen, powerlifters, and bodybuilders can benefit from overreaching much longer than several days at a time, gymnasts, fitness sport participants, and weightlifters rely too much on precise technique to be able to afford to overreach for longer than a week at a time.

Peak Power

After several days of training in a highly fatigued state, power begins to measurably decline. The product of force and velocity, power depends on the production of both speed and strength. Though speed falls off just before power, stable strength levels can keep power elevated for several days after speed begins to drop. In order to effectively overload power, high power outputs must be achieved in training. If the athlete becomes overreached and cannot express high power in training, the training leads to virtually no improvement, and continues perpetuate fatigue. Overreaching for power for longer than a week at a time conditions athletes to perform under their best abilities, or doesn’t allow for further power improvement.

Strength

Strength begins to decline after about two weeks of overreaching, but is reversible and super-compensatory if overreaching periods do not exceed 3 weeks. Because strength is easily measured and more resistant to decline, decreases can be a meaningful indicator of counterproductive fatigue levels.

Athletes seeking to improve in strength via functional overreaching have to overreach for at least a week but can do so for as many as two weeks. This means that a substantial portion of the training will take place after overreaching has begun. It’s normal for a strength athlete to feel that they are underperforming in terms of technique and speed when properly training for functional overreaching. Strength athletes will be carrying a considerable amount of fatigue compared to high technique or speed athletes.

While we have described the case where strength athletes bear a disproportionate amount of fatigue with respect to their technique and speed counterparts, observing the prescribed functional overreach period is no less critical for the strength athlete than for these others.

Body Composition Changes

As fatigue aggregates, the net metabolic balance of the body begins to shift towards catabolism. In the early stages of a mesocycle or training block, there is still plenty of anabolic activity to continue driving muscle growth. After several successive weeks of overreaching, catabolic processes begin to outpace anabolic processes, and muscle growth slows substantially, stops, or even reverses, resulting in muscle loss. At the same time, though less aggressively than muscle loss, fat loss is also prompted by fatigue-driven elevations in stress hormones like cortisol in the overreached state. Such a catabolic environment helps explain observations in athletes in extremely overreached states that show a simultaneous increase in relative body fat percentage, while muscle mass and even body weight decline. This is certainly no recipe for peak performance in nearly any sport, physique sports especially.

The first big implication here is that those athletes mainly concerned with physique development can chronically hold onto much higher levels of fatigue (and benefit from much larger training volumes) than athletes involved in technique, speed, power, or even strength focused sports. This is very good news, because the prolonged hard training and hypocaloric dieting required to peak for stage shape in physique sports is a very fatiguing endeavor. If technical, speed, power, or strength athletes wish to train like physique athletes for aesthetic goals, it's best done deep in the offseason when performance in their chosen sport is not an immediate concern. Although the evidence strongly supports the use of overreaching for hypertrophy (increasing muscle mass), its efficacy is not entirely clear. What is reasonable, however, is that, due to the high volumes needed for muscle growth and maintenance, physique athletes will generally carry (on average) a higher degree of fatigue than most strength and power sport athletes.

Though it takes weeks to occur, eventually a prolonged overreaching period will in fact affect muscle and fat ratios–this is when overreaching becomes detrimental for physique athletes, and is long past decline in non-aesthetic fitness characteristics. From this point, the risks of continuing to push training become more bleak.

Increased Chance of Illness

The longer fatigue is sustained, the more physical resources the body requires to ameliorate it. The more resources being diverted to recovery from the fatigue of training, the fewer left to effectively deal with potential pathogens and disease agents. Thus, as fatigue levels climb higher and remain un-attenuated for longer, the chances of the athlete falling ill escalate. Because sickness puts an even greater demand on recovery systems, fatigue rises higher still. If hard training is continued through illness, the illness will often become more severe (head colds giving way to chest colds and fevers and so on). There is no specific time frame for illness risk to occur with respect to fatigue, but the chances increase exponentially as fatigue increases and goes unalleviated over time.

Increased Injury Risk

The relationship of fatigue levels to injury risk is very similar to that of illness. Injury risk becomes exponentially greater as fatigue rises and continues to be sustained. Interestingly, the risks of injury that lies in fatigue progression are due to different causes at different timepoints. When technique expression becomes compromised early in the overreaching phase, an increase in injury results primarily from missteps and mistakes in movement by the athlete. Trips and falls, bad landings, and technical errors with barbells constitute the vast majority of elevated risks in this phase of overreaching. During moderate overreaching, injury risk isn't as high as would be expected, because reductions in power and strength often reduce the overloads one can present in training. If the overloads aren't as great, neither are the chances of injury. In very prolonged overreaching, microtears to the tissue become common, and pronounced enough that macro tearing (much less innocuous than its micro counterpart) is a heightened concern, even without very overloading training. So the chances for small wear and tear injuries goes up rather linearly through fatigue accumulation, while the likelihood of major trauma is likely highest (especially in highly mobile sports with running and jumping components) in the earlier phases of overreaching.

The highest chances for major traumatic injury (muscle and tendon ruptures) seems to be when an athlete who often overreaches - and doesn't take enough time to sufficiently bring fatigue back down - takes a break from hard training just long enough to recover high levels of strength, power, or speed abilities, and then returns to play. When technique expression has not yet returned, the tissue damage (which takes a very long time to heal) that predisposes us to injuries is still largely present, and the overloading forces capable of causing injuries are reintroduced. Essentially, this means that if you have been overreaching often and for prolonged periods and take a break from training, but then return to train hard, this is hypothetically the most highly injury-prone scenario possible. You've still got the microtrauma from weeks and months of overreaching, and possibly some remaining lack of coordination in your movements, but now you also have the strength, speed and power to propel your limbs with enough overload to turn those microscopic rips into large ones, or make a movement mistake with great force and cause a major injury.

So, while it's true that injury risk does escalate with rising and accumulated fatigue, it pays to understand that just taking a few light days from that highly overreached state is not enough to greatly reduce injury risk, and might actually increase the odds for the most traumatic kinds of injury.

Overtraining Syndrome

Functional overreaching is when the overreached state is planned and maintained just long enough to yield the biggest benefits in supercompensation. After fatigue has been dispelled, performance is higher than ever, and the athlete can benefit from this cycle regularly. Non-functional overreaching is when fatigue is maintained at too high a level or for too long, and the athlete is left with no net improvement after fatigue is alleviated: certainly not a preferred outcome.

If the high fatigue state is maintained for much longer than the point at which functional overreaching becomes non-functional (on the order of a month or longer) a physiological state called *overtraining* occurs. Overtraining results in a net *decrease* in performance. With the less severe kind of overtraining, the athlete eventually regains their lost performance and can make future gains, though reclaiming prior performance levels is neither automatically nor easily accomplished, but, rather, just as difficult as it was to achieve in the first time.

The second, more severe kind of overtraining results in decreased performances that *never* return to baseline levels. Full recovery literally never occurs, and the reasons for this are still somewhat mysterious. It's possible that the summation of chronic injuries and inflammation create an environment in which normal training volumes and intensities can never again be sustained. The details and exact mechanisms of this unfortunate state have yet to be elucidated, but it is clear that in order to avoid overtraining and any unwanted detrimental fatigue effects, we must be able to monitor fatigue. The good news is that there are multiple tools and signs by which to do this, and the next section lists and describes them in detail.

Section 5: Detecting Fatigue

When left untreated, fatigue can negatively impact performance, our ability to recover, our ability to progress over time, and can even increase our potential for injury. As such, a primary focus for sport scientists is to monitor fatigue and estimate its relative impact on the training process. Fatigue monitoring requires a variety of quantitative and qualitative tools and assessments in order to make evidence-based decisions on how to direct training. These checks can range from simple ones, like asking an athlete how he's feeling that day, all the way to complex analyses of a season's worth of in-game statistics.

The savvy sport scientist seeks to proactively predict and control fatigue, thereby preempting its adverse effects. To do this, the fatigue monitoring toolbox needs to contain indices that predict when fatigue is on the rise such that it may be problematic, tools for measuring it in an athlete's current state, and benchmarks that indicate whether an athlete has already gone beyond the tipping point of acceptable fatigue levels. Although each of these measurement time-points is independently useful, the best monitoring results will come from an integrated approach.

In the following discussion, we will explore two important aspects of detecting fatigue, the warning signs to look for, and how to interpret them. We will go over methodologies for tracking evidence of impending or already accumulated fatigue, and determining when a reduction in fatigue is needed to allow safe and productive training to continue. Keep in mind that the goal is not to avoid becoming fatigued entirely! Rather, it is to train hard, and let fatigue rise slowly, then bring it down in time for a competition or simply to ensure continued performance optimization.

Before we begin our discussion on fatigue indices, it's important to understand that just one indicator is never enough to draw a definite conclusion about the state of fatigue. If several indicators are present, it is likely that the athlete is fatigued, and the more indicators there are, the higher this likelihood. We would like to have a silver bullet fatigue indicator for each timeframe, but in the real world we face several limitations.

The need for multiple concordant fatigue indicators to confirm an impending, current, or long term state of high fatigue stems from multiple factors. First, all forms of measurement have an inherent margin of error, especially those that are subjective (aka, when athletes self-assess how tired they're feeling). This can be due to properties of the measuring tool, such as accuracy and sensitivity. Second, factors unrelated to fatigue can influence a measurement. If your jump height is down, it might be because you sat in a car all morning on a long road trip and are stiff during the test. Errors in measurement and noise from non-fatigue variables can skew any single assessment, and lead to a false conclusion that you are fatigued. When more than one fatigue indicator is used, the additional data decrease the chances of an erroneous conclusion that high fatigue is present. If your movement speed is slow but the weight feels great on your back, it's unclear if fatigue is the primary cause. If a normal training squat weight feels like it's crushing you but your movement speed is above normal, it's tenuous for us to conclude that your fatigue is elevated. If the bar is moving slowly *and* the weight on your back feels like it's crushing you, we could draw a stronger conclusion that fatigue is accumulating.

Leading Indicators

Leading indicators are the early signals that fatigue is on the rise. Though it may not be problematic at the time, the presence of these indicators suggests that the effects of heightened fatigue may soon manifest, typically within about a week's time from the detection of one or more leading indicators. Ergo, observing the leading indicators of fatigue allows us to proactively plan for fatigue management, versus merely reacting to it with no forethought. Waiting until the onset of high fatigue has passed can mean the difference between a productive functional-overreaching phase and a non-functional waste of training time.

If you detect these leading indicators, it's not yet time to reduce training, but you should expect to make adjustments to the remainder of your plan in the near future. Even though we use leading indicators to allow us to be prepared for fatigue when the time arrives, you might still find these indicatives stressors in the middle of a normal training cycle. This will warrant some training adjustments be applied *ad hoc*. You might have a problem with your program design or your recovery efforts and need to take this into consideration when you plan your next program. In contrast, if no indices of fatigue are detected, even during a planned overreach week, the athlete may be under-training.

Let's identify and discuss six main leading indicators and what they mean for fatigue management:

Recent Nutrition

Under-eating calories, carbs, and protein can greatly blunt the body's ability to recover. Poor nutrition can be a direct cause of fatigue, but can also serve as an indicator. Missing meals unexpectedly may be inevitable at times, but coaches and athletes should recognize that subsequent training sessions may not go as planned if this has occurred. In the same vein, frequently missing meals can become a serious problem. If this is the case, we can predict that impending fatigue levels will rise more quickly than otherwise expected.

Recent Psychological Stress

Maintaining low psychological arousal and stress levels in your personal life also plays a substantial role in fatigue management. If your training and nutrition are great, but you're frequently arguing with a loved one or you're missing sleep, you can predict that your ability to recover from normal training stressors will be reduced. One really bad day can bring stress levels high enough to impact training and recovery. Without relief bad days can become bad weeks, and the training process can suffer. When it is not possible to prevent or reduce external stress levels, the best we can do is take notice of them and adjust our training accordingly so as to prevent excessive fatigue accumulation.

Recent Physical Task Level

Physical work outside the gym can contribute to overall fatigue just the same as work done at the gym. Although the amount of physical labor required by a given job or hobby varies, it's safe to say that the physical stressors from activities of daily living can accumulate right along with the rigors of training. Even if the daily work you're doing isn't particularly intense, doing 30 hours of it in 3 days can result in measurable fatigue. If you're planning to work for an unusually long time or up the physical intensity of the work you are doing, be prepared to adjust other variables in your training and recovery plan in anticipation of higher levels of fatigue.

Recent Microcycle Training Load

Though it might seem obvious, it bears repeating that how hard you train in a given week can affect how you feel during the next week's training sessions. Achieving a big PR on a lift feels awesome in the moment, but the fatigue resulting from this effort may wipe you out for the remainder of that week, and possibly beyond. Likewise unplanned or unusually hard training sessions may push you over the edge. Normally, your hardest training is already programmed to occur right before a deload, which is a great alignment. When this is not the case you must take steps to manage fatigue before it becomes deleterious. A common mistake is to assume that your body will "just deal with" and dutifully manage the extra stress to which it's been subjected. But in the absence of a conscious effort on one's part to help it do that, this simply isn't true.

Technical Coordination and Learning Proficiency

Fatigue can negatively impact your ability to learn new techniques, as well as refine and express those you already know. Noticing that you are losing the 'mind muscle connection'— your lifts are feeling awkward, your body not doing quite what you want it to do—are valuable indicators. The good news is that you can train through a lot of these side effects and still benefit from that training. The bad news is that this degradation in performance is a sign that very high general fatigue is on the way. As these variables are generally only qualitatively assessed and can be subjective, conclusions about fatigue state should be supported with additional indicators.

Jump Height

Jump height is an indirect measure of power output and is correlated with performance outcomes in nearly all sporting activities. While jump height is a potentially useful indicator of fatigue, it has its limitations. The first problem with jump height is that it's not very precise, making it difficult to conclude that fatigue is problematic solely based on jump height data. The second problem with jump height as an indicator in personal and practical use is that any accurate measurement is going to require equipment. This can be simple mechanical equipment like jump and touch flags, more involved equipment like an electronic jump mat (where the athlete jumps from a touch sensitive device that estimates jump height based on jump timing), or even a force plate (which more precisely measures jump height using ground reaction forces). Lastly, jump height is limited by the need for extensive data collection for longitudinal comparison. Unless you have at least a week's worth of average jump height data, it's not possible to conclude that your jump height has decreased on the order of meaningful statistical significance. While jump height is of very limited use for individual athletes, testing entire teams several times a week can be a great way to monitor average fatigue levels and manage training loads.

Concurrent Indicators

Concurrent indicators of fatigue are those that arise at the same time as fatigue itself. Whether or not we act immediately to reduce this fatigue will almost always depend on which performance characteristics are being affected relative to our training or competition schedule. There are planned times throughout the year characterized by expected losses in performance that we choose to accept, such as general preparatory periods and overreaching periods. These losses are strategic, and potentiate gains following recovery periods. Conversely, there are times throughout the year when performance losses are not acceptable, and should be dealt with swiftly. Concurrent indicators help assess whether or not athletes are in an acceptable training state relative to where they are in their season or training cycle.

Unfortunately, concurrent indicators can be misinterpreted. The presence of any amount of fatigue does not necessarily mean that training should come to an immediate halt. Likewise the absence of fatigue does not necessarily mean that training needs to be ramped up. Detection of a single concurrent indicator can help lead to these conclusions, but requires corroboration. At this time, there are four concurrent indicators worth considering:

Movement Velocity

Losses of velocity come before strength losses, and are among the first concurrent indicators of fatigue. These can be losses in sprinting velocity (as measured directly by laser gun or indirectly by sprint times), punching, kicking, throwing, and bar movement velocities. If you have access to velocity tracking equipment, you can use velocity measurement to a huge advantage. Tracking movement speeds allows you to both assess fatigue and determine whether appropriate overloads of power and speed are being applied in training. Although decreases in movement speed can be meaningful indicators of fatigue, it is debated how much loss is acceptable. Some measurement tools such as stopwatches, timing gates, or speed guns are relatively easy to use. More complicated assessment tools such as potentiometers, accelerometers, or other kinematic devices can make assessment more cumbersome, and also require an abundance of load-velocity data on each athlete for analysis, which some coaches may find impractical.

Perception of Effort

Although more qualitative, perception of effort—how heavy the bar feels when lifting, how arduous your standard soccer practice seems, etc.—can be used to detect the presence of high-order fatigue. Feeling like your typically manageable training is particularly difficult and overly strenuous is generally a sign that it's time to take steps to manage fatigue. That said, we all have bad days, so don't deload every time you don't feel your best. Back off to alleviate fatigue after several consecutive sessions of regular training that feel unusually taxing.

Relative Performance

In addition to your training feeling more difficult when you're carrying a high level of fatigue, performance can also noticeably decline relative to your baseline performance. Being unable to reproduce typical top performances is a big part of the definition of recovery. Changes in relative performance can be observed in any sport or athletic endeavor: a runner who can normally maintain a 6 minute mile pace starts to creep closer to 7-minute-miles, a basketball player who typically averages 10 rebounds per game gets only 6, a soccer player who normally covers about 2 miles of running during practice drops down to 1. Relative performance as a fatigue indicator is very practical because it can often be assessed based on exercises and efforts that you're already training and do not require any additional equipment or resources. For the most part, if you are performing up to your own standards, you probably have nothing to worry about as it relates to fatigue. When performance begins to noticeably decline, it might be time to let up and recover. In our collective coaching experience, performance drops due to high fatigue usually tend to be hard to miss. In other words, if you are unsure if your performance has declined, it's unlikely that you're in an overly fatigued state. It will be obvious once performance has dropped enough to call for recovery interventions.

Strength

Because strength is so resilient to the effects of fatigue, decreases in strength should be taken seriously. One of the most common ways of measuring strength in the context of detecting fatigue is grip strength. Grip strength might seem like an odd means to assess changes in strength, but because it is easy to measure without itself generating large amounts of fatigue, it is an excellent method for non-invasive assessment. Although a similar result can be obtained from relative performance measures, such as looking at lifting numbers across weeks, these rely on the execution of normal training. This of course comes with normal fatigue, and hence carries with it increased risk of injury and suboptimal training from non-functional overreaching over the course of the assessment.

A hand-grip dynamometer measures grip strength, is inexpensive, and is easy to use. It takes about a minute to perform the test and generates so little fatigue or injury risk that it can be done daily. There are, however, some very high ecological validity problems with this method of assessment. A program with a high volume of squatting can result in a great deal more total fatigue than a program with a high volume of pull ups, but the forearms will develop quite a lot of fatigue from pulling training and very little from squatting. In this case, a grip strength test would potentially under-detect general fatigue in the squatting program and over-detect general fatigue in the pulling program. This type of detection difficulty is one of the many reasons that even the best fatigue indicators are not recommended for standalone use.

Actual Competition Performance

This indicator is a last resort for determining whether fatigue has gotten too high. If the more negative effects of fatigue are manifesting on game day, something went wrong in our training program long before that moment. Poor performances can happen for all sorts of reasons, but, if other lagging or concurrent indicators are present on meet day, accumulated fatigue is probably a contributor. Though it is a great disappointment to have creeping fatigue sabotage our competition performance, not all is lost. As long as we manage to avoid injury as a result of fatigue during your competitions, we can use this mistake to instruct changes to our training plan in preparation for our next competition.

Lagging Indicators

Lagging indicators are those evident after fatigue has already been high for a long time—two or more weeks. Using these as your primary indices often leads to identifying fatigue after it is too late to recover from it. Sometimes, both leading and concurrent indicators can be missed, masked, or misinterpreted; that we end up carrying unproductive levels of high fatigue that hamper our training and performance. Lagging indicators in this case can confirm that the athlete has begun flirting with non-functional overreaching (whether they know it or not).

Lagging indicators have two primary uses for athlete monitoring. First, they can be used to gauge fatigue during functional overreaching. Occasionally we want to keep training hard and hold fatigue high for a time before letting it fall, so that supercompensation can occur. The duration for which lagging indicators are expressed can dictate when to end an overreaching phase so as to keep it functional. Second, lagging indicators can serve as near-definite stop signs for normal training, not characterized by overreaching periods. If you are presenting with several of these indicators during normal training, you're almost certainly well into overreaching, and probably need to back off.

Heart Rate Variables

There are three methods of heart rate measurement that can reveal heart rate changes indicating a high fatigue state:

Heart Rate Variability (HRV) is the degree of variation in time between heartbeats. Under normal circumstances, there is a fair amount of variation in the time between beats. As fatigue rises, heart beats actually begin to occur with less between-beat variability.

Morning Resting Heart Rate (MRHR) is a measurement taken immediately upon waking. MRHR is increased from baseline when fatigue is high.

Recovery Heart Rate (RHR) measurement is performed following exercise. This measures heart rate in intervals immediately following exercise, and determines the amount of time post-exercise needed for the athlete's heart rate to return to baseline. The longer the heart takes to return to its at-rest rate after a given exercise, the more fatigue the athlete is likely carrying.

Part of the problem with all of these heart rate assessments is that for changes from baseline to be large enough to be accurately detected and determined significant fatigue must have been very high for weeks. Another issue with using any heart rate measurement to assess fatigue is that data are inherently noisy and unreliable. Days of consistent measurement under low fatigue, low stress conditions are required to establish a baseline for comparison, and a host of variables can skew the data during collection. Individual assessment is rarely reliable unless it is in conjunction with team averages, where other individuals undergoing similar training help assure that fatigue detection is not due to noise in one individual's data. Another downside of relying on heart rate data is that if fatigue is detected using these data, it is almost certainly very high, but, we cannot conclude that the reverse is also true: the absence of detectable fatigue using heart rate data does not prove the absence of high fatigue. A lack of changes in heart rate data do not necessarily mean a lack of changes in fatigue levels.

Desire to Train

With enough fatigue, even the most motivated athletes will start to lose their desire to train. We all have sessions here and there that we'd rather skip. When motivated athletes have a consistent pattern of sessions like this, it can be a significant indicator of high accumulated fatigue. This lack of passion can manifest in not wanting to train at all or as boredom with one's training plan, replaced by the tendency to "switch things up" and do different types of training. If you are normally a motivated and dedicated athlete but feel a strong need to get away from your normal training or stop it entirely, you're possibly very fatigued, especially if other indicators agree.

Mood Disturbances

When carrying high fatigue to the point of overreaching, many people will begin to have disturbances in their mood. This usually presents as increased anxiety, restlessness, irritability, feelings of helplessness, or lack of desire to do normally enjoyable activities. Inappropriate or erratic emotional responses can also arise. Because so many other factors can influence mood states, this by itself is not a powerful indicator. Very seldomly can mood indices alone have practical significance, and are generally limited to measures of anxiety and feelings of helplessness. If other indicators agree, and such mood alterations are uncommon for that individual, their manifestation can solidify the conclusion that high chronic fatigue is present.

Appetite Suppression

Decreased appetite is a common symptom of overreaching. This sensation can be a strange lack of interest in eating food (even especially tasty food), the feeling that preparing or acquiring food is an inconvenience, and the inability to eat a normal portion of food in one sitting due to low desire. This is an especially serious sign of uncontrolled fatigue during a hypocaloric weight loss diet. Normally, weight loss diets upregulate hunger so much that loss of appetite seems counterintuitive. If your appetite diminishes even though you're deep into a cut, you might have a serious fatigue problem, and you'll usually find other fatigue indicators that echo this assumption. Fatigue-tolerant bodybuilders in particular should keep track of this factor. When you're on a fat loss diet for a show, being hungry is normal. If you stop being hungry, you might be overly fatigued and losing muscle.

Sleep Disturbances

High-order fatigue can result in insomnia, an inability to fall, or stay asleep or to get quality sleep. Individuals with high fatigue often have trouble falling asleep, will wake up much earlier than they intend, and may have bad dreams and multiple bouts of wakefulness throughout the night.

Illness

As mentioned in the last section, a very lagging and belated indicator of fatigue is illness. As a result of overreaching, the immune system can be suppressed, increasing the probability of sickness and infection. Illness can occur even when you're fresh, and it can also be a cause of fatigue versus rather than the result. If the other lagging indicators align, illness means that it's time to take it easier in training.

Wear and Tear Injuries

Acute injuries can happen at any time. You can be in the best shape of your life and pop a quad or a pec, simply because you are strong enough to do so. Likewise, wear and tear injuries like aching elbows and rusty knees follow many of the best athletes, not just when fatigue is high. Chronic high fatigue can prevent existing injuries from healing completely and allow new injuries to creep in. Push too hard for too long and your microtrauma quickly becomes a macrotrauma. It’s best to reduce fatigue before you notice this cascading injury effect. Failing that, make adjustments to your training as soon possible to avoid worsening injuries.

The table below summarizes the leading, concurrent, and lagging indicators of fatigue.

Table 1: Indicators of fatigue

INDICATORS OF FATIGUE

Leading	Concurrent	Lagging
Recent nutrition	Movement velocity	Heart rate variables
Recent psychological state	Perception of effort	Desire to train
Recent physical task level	Relative performance	Mood disturbances
Recent training load	Strength	Appetite suppression
Technical coordination	Competition performance	Sleep disturbances
Learning proficiency		Illness
Jump height		Wear and tear injuries

Rising fatigue →

Before we close out this chapter, a quick recommendation on the use of fatigue indicators is warranted. New technologies are great and in the future many of them will be incredibly useful tools with which to detect fatigue. At the time of this writing, the subjective and low-tech measurements are currently still the best and most practical tools to utilize as the mainstay of your fatigue detection strategy. Sleep, nutrition, stress, perception of effort, performance, desire to train, and sleep quality are tried and true indicators that will rarely steer you wrong if used in conjunction with each other. Where technological novelties can be expensive and will inevitably become obsolete, the guidelines given here are free and reliable.

It cannot be stressed enough that one measurement alone is insufficient to determine the fatigue state of the athlete. In order to clearly establish that fatigue has become problematic and eliminate false positives, we recommend confirming that at least one measurement from each of the following categories has been negatively influenced:

- Performance
- Physiology implicated in training
- Psychological state

Recovery is as important to progress as overload training. This means that one must take care to identify fatigue and recover. To do so, it's crucial to accurately identify fatigue and attempt recovery neither too deep into a fatigued state nor too early into overload training. When we detect at least one indicator from *each* of the above categories, we can be sure that we are not mistaking laziness or a bad day for true fatigue.

2 RECOVERY

Section 1: Defining Recovery

As defined earlier, *fatigue* is “the disruption of physiological systems that leads to a decrement in athletic performance”. Let’s now define recovery as:

> *The return of physiological systems to baseline, which results in a restoration of athletic performance to pre-disruption levels, or at least to levels sufficient for further overload training.*

This can be broken down into simpler terms: Reaching a recovered state means that your body has sufficiently repaired such that you are able to, at minimum, perform overloading training again. A total recovery will return the athlete to pre-disruption levels of performance (or to even higher levels if underlying adaptations have been made and are being masked by fatigue), but this full recovery is not always necessary.

Something to note is that all psychological systems arise from physiological systems. We can assume that the above definition of recovery accounts for all training related, psychologically-based recovery—such as a return to a motivated state after the desire to train had been lost—as well as purely physical recovery, such as the healing of micro-tears in the muscle tissue. It is important to note that, just as we are not discussing recovery from injury in this book, we are not discussing recovery from mental illness or trauma. When we refer to psychological recovery here, we mean alleviation of the normal mental stress and fatigue accumulated by athletes in the course of training and daily life.

While recovery *can* be concurrent with adaptation—the improvement of physiological systems implicated in training—it *is not absolutely necessary.* In other words, it’s very possible to have total recovery, but no adaptation. If systems heal completely and perform just as well as before, we would still say that the system in question has fully recovered, even though there are no gains. The dictionary definition of the word “recovery” is simply the replacement of something that was lost or depleted, with no implication of anything additional getting “thrown in”. Adaptation is not guaranteed by recovery—it is beyond just recovering. To adapt one must not only recover, but also improve. In sport science lingo, recovery and adaptation are often conflated because training protocols regularly pair the two. With Recovery-Adaptation (RA) appearing throughout the sport training world, it’s easy to assume they are synonymous. While it's true that the R and the A very often go together, it's important to remember that recovery can come independently of adaptation, a concept we will cover in detail later. That said, it's critical to understand that, while recovery can happen independently of adaptation, *adaptation does not occur without recovery*.

Lastly, recovery as defined may not always be total recovery. Recovering enough to perform overload training again is enough in some cases, but reaching peak performance for important competitions might require recovery beyond that point. In order to determine what type of recovery is appropriate, the timescale variable will be examined.

Timescales of Recovery

Recovery can occur on several timescales, all of which are relevant for consideration. Some degree of recovery must occur between hard efforts within a single training session in order to perform multiple efforts. Recovery on this scale is dictated mainly by within-session training volume and density. Recovery on micro and mesocycle scales becomes more complex as it can involve a variety of recovery strategies that include both training-structure design and additive measures. Even long term annual or macrocycle recovery strategies should be considered in good program design. Each level of recovery planning plays its own critical role in allowing an athlete to consistently make progress across the days, weeks, and years of an athletic career.

Within-Session Recovery

Within-session recovery refers to that which will allow overload training to be maintained throughout a single training session. There is a misconception that overload requires total recovery between hard efforts. Although this seems logical, it is incorrect. Resting enough to achieve total recovery between efforts during a single session would make any given session inordinately long. Luckily for all of our busy schedules, *full* recovery between efforts is not necessary.

We established that recovery occurs when the athlete can resume the intensity and volumes needed for overload training. For endurance athletes, this means taking only enough rest or reduced effort to maintain race pace, lap times, and total distance traveled within a training session. For physique athletes (outside of specialized training methods like metabolite training), this generally means being able to continue lifting without having to drop the intensity below ~60% of 1RM to maintain reps and sets, or not having to drop the sets and reps to maintain intensity. For strength athletes, this means maintaining the relative intensity of the session; for power athletes, this means maintaining at least 90% of the maximum power or speed within the session.

Within-session recovery is primarily regulated by managing the amount of time spent resting, as well as the activity between efforts. With the exception of very large and strong athletes who may require slightly more time, taking rest times of 2-5 minutes between sets is generally sufficient to promote repeated overloading efforts within a training session. During these rest periods, athletes should generally conserve physical and mental energy by getting comfortable and moving the trained muscles lightly. Poor work capacity may also hamper within-session recovery when the athlete cannot sustain overloading efforts. If the athlete becomes prematurely exhausted during a session, they may need to consider developing their work capacity before moving on to more intense training phases. When the athlete is not fit enough to train at a level sufficient to overload, recovery is no longer the limiting factor for progress.

Session to Session Recovery

One of the most important timescales for recovery is between two training sessions within a microcycle. This is not to be confused with recovery in a week's time between two of the same training sessions. We are referring to the ability to have another overloading training session within the same week (or even on the same day). This session will often be different from the one we're recovering from. A fitness sport athlete's session to session recovery might focus on the ability to overload in a metcon workout at 4pm when strength had been trained at 10am that same day. For a powerlifter, session to session recovery may allow us to have an overloading bench session the day after a very taxing squat session.

Session to session recovery is a cornerstone strategy because the number of quality overloading training sessions an athlete can have in a typical microcycle (a week or so) has a large effect on the magnitude of their gains. Optimal session to session recovery allows for maximum overload training each session, and so sport performance will increase at a faster rate.

Microcycle to Microcycle

A microcycle of training is the period of time in which an athlete completes a series of training sessions. When the athlete moves to the second microcycle, he or she generally repeats the same series of training sessions as performed in the first microcycle. If a powerlifter has 4 sessions total of squat, bench, deadlift, and accessory training during a training week (in that order), the second squat training session after starting the program will be the start of the second microcycle. Once an entire rotation of squat, bench, deadlift, and accessory days has been completed, another microcycle begins, and so on. The vast majority of training cycles are designed with microcycles that are one week in duration.

The definition of microcycle to microcycle recovery is the restoration of enough performance ability to present an overload in training during the following microcycle. In a traditional accumulation phase, microcycles summate training loads week to week and lead into functional overreaching phases; the training must become harder with every week in order to result in the progressive overload that is responsible for gains. Microcycle to microcycle recovery drives longitudinal overload training cycle over cycle, or week to week. In order to satisfy the progressive component of overload, during training phases, microcycle to microcycle recovery means that the athlete is able to perform harder training in each subsequent microcycle within a training phase. By contrast, during phases without functional overreaching, such as midway through a hockey season, microcycle to microcycle recovery simply means week to week maintenance of abilities.

Mesocycle to Mesocycle Recovery

A mesocycle is a collection of microcycles that make up a “block” or dedicated period of specific training, lasting around 4-6 weeks. Mesocycle to mesocycle recovery describes a more moderate, month to month timeline of recovery, and allows productive training cycles between different phases of training. After several weeks of accumulating overload training, the athlete begins to feel the effects of both acute and accumulated fatigue. Glycogen depletion, increased basal sympathetic nervous system activity, microtrauma, and stress hormones can all begin shifting the body’s net balance toward catabolism. Catabolic activity can decelerate, stop, or even reverse the recovery-adaptive processes.

As we look across mesocycles of training, we find a need for strategies to address acute and chronic fatigue. If no recovery measures are taken within or between mesocycles, the athlete will not be able to overload train from one cycle to the next, resulting in declining gains.

Mesocycle to mesocycle recovery is pivotal in fatigue management; the effects of hard training can either manifest as glorious performance improvements, or as crippling non-functional overreaching. Recovery between mesocycles is essential to phase potentiating long-term performance improvements and developing a periodized training program.

Macrocycle to Macrocycle Recovery

Macrocycles are simply a series of mesocycles. A macrocycle of training is typically a period of 4 months to a year and marks the duration between one major competition and the next in individual sports, or one season and the next in team sports. Some causes of fatigue can take so long to recover from that entire portions of a macrocycle need to be dedicated to ensuring that they don’t continue to accumulate and eventually cause trouble at the mesocycle level and below. These causes of fatigue are:

- Connective tissue microtrauma
- Intracellular signal disruption
- Psychological burnout and demotivation

Typical wear and tear to connective tissues such as fascia, tendons, ligaments, and bones occurs and heals, at least to some extent, within each mesocycle. However, connective tissue damage can accumulate slowly over multiple mesocycles and eventually become an obstacle to overload. This problem usually manifests as an injury to one of the aforementioned tissues. Poor or unsafe technique can be a contributing factor to microtrauma-induced injury, and injuries can occur years down the road.

With months of training at high volumes, AMPK (and other such catabolic molecular pathways) activity can begin to predominate over mTOR (and other such anabolic molecular pathways) activity, shifting the net balance toward catabolism and away from recovery. As this is a longitudinal process, an athlete can still overload as catabolism increases. As you can imagine, more overloading will push the body’s equilibrium further toward catabolism, and eventually its effects will become apparent as the athlete’s adaptations slow or reverse. In addition, athletes may also find that their ability to recover acutely from training has diminished, and that recovery takes more time than usual.

Lastly, the psychological rigors of training can manifest as burnout, characterized by a decrease in motivation or desire. Though we often only think of the physical effects of training, the monotony, dedication, and stress of hard training and competitions is one of the primary reasons that athletes take a hiatus.

Section 2: Recovery versus Adaptation

Though recovery and adaptation often come together, it is important to note that recovery can come without adaptation, or even at the cost of adaptation. On the other hand, adaptation does not come without recovery. To improve at the fastest possible rates, we have to distinguish between these two processes. First, let’s review some definitions:

Recovery: *The return of physiological systems to baseline, which results in a restoration of athletic performance to pre-disruption levels, or at least to levels sufficient for further overload training.*

Adaptation: *The improvement of systems above baseline characteristics after overloading training, making the system more capable than it was before the stimulus*.

There are a variety of circumstances under which recovery occurs without or with reduced adaptation. These can be leveraged as a strategic aspect of a training plan.

Recovery-Only Training Volume

It turns out that we can recover from a larger volume of training than would be productive for adaptation. The process of adaptation requires energy and resources. If you accumulate so much fatigue that your body’s recovery mechanisms are overwhelmed, your body will prioritize recovery over adaptation for improvement. In most cases, you want to train within a range that allows your body to recover and still have resources for adaptation. In any training program, we must be mindful of doing too much because overexertion will leave us without any resources for adaptation.

To put it simply, you can train so much that it prevents improvement but you still manage to recover. Although this may seem contradictory to the training principles we are educating, there are some instances where this is actually the goal. In-season athletes who have multiple games across a short time period might need to train above their Maximum Adaptive Volume (MAV) and at (or close to) their Maximum Recoverable Volume (MRV) in order to cover all of these events. In this case, adaptation is not the priority. Instead, players are trying to recover just enough to maintain their fitness for optimal repeat performance.

In addition to being useful in situations like the one described above, training consistently at your MRV is also effective on the microcycle scale. Training that hard can lead to functional overreaching, and with planned recovery can result in supercompensation (yielding adaptation).

Training in this way requires a dedicated recovery period following overreaching. Considering the time frame, it must be saved only for the tail ends of training phases, immediately prior to a recovery phase. If this type of training is done for too long, potential adaptations are lost, as the resources needed for recovery are sapped from the processes of adaptation.

Adaptation-Suppressing Recovery Modalities

Certain recovery modalities can blunt adaptation. Some examples are non-steroidal anti-inflammatory drugs (NSAIDs) like ibuprofen and cold therapy (like icing or cryotherapy). Taking some Advil™ or icing your sore legs can promote recovery, but it comes at the cost of adaptation. Using these interventions does not altogether eliminate adaptation, it just reduces it in a small but measurable way. For those looking to make the most progress from their training, these should be used judiciously or not at all. For a combat sport athlete who needs to practice technical skill, spar, train for endurance, and weight train during his/her weekly regimen, trading off some adaptation for enough recovery to get through the week may be worthwhile. Likewise, for athletes trying to peak their performance before a competition, the boon of full recovery may far outweigh the consequences of a small forfeiture in adaptation during that time.

Trade-offs come up repeatedly in the scope of organizing training and recovery, and suppressed recovery modalities are yet another example. Some recovery methods slightly reduce adaptation from its maximal potential, but there are times when these trade-offs are advantageous.

Section 3: The Volume Landmarks and Recovery

One of the most fundamental questions in all the sport sciences is "how much training should we do?" It's clear that overload training enhances fitness and sport related skills and tactics, but it also generates fatigue. The pros and cons of overload come as a package deal, making fatigue management necessary to offset the fatiguing nature of overloading. Many training programs are multifaceted, with strength training, endurance and sport related components, which can lead to the aggregation of a variety of fatigue effects. Our goal is then to train hard enough to make gains while still managing fatigue across our recovery timelines, from within-session to macrocycles and at every time scale in between.

This idea, along with available data as well as our observations in the field, has led to the development of a set of classifications we call the training Volume Landmarks, to which we've dedicated our book *How Much Should I Train? (An Introduction to Training Volume Landmarks)*. The Volume Landmarks provide the nomenclature needed to describe the complex nature of training dose-response relationships and bridge the gap between Overload and Fatigue Management principles. In general, we know that the more of any given type of training is done, the more potential gains can be earned from it. The catch is that fatigue is directly proportional to training volume, and our ability to recover and adapt is compromised with increasing levels of fatigue. This makes recoverability a major limiting factor for continued progress. Our ability to recover is influenced by genetics, the athlete's current physical abilities, and lifestyle factors. We cannot do much about our genetics, but our physical abilities and lifestyle factors can be managed to match the rigors of our training.

In order to do so, we first need some critical pieces of information:

- What is the minimum amount of training needed to maintain existing fitness, skills, and tactics?

- What is the minimum amount of training needed to make any significant and measurable progress?

- What is the maximum amount of training the athlete can sustain before overreaching occurs?

- What is the optimal dose of training, and how does it potentially change under different conditions?

While these questions may seem straightforward, answering them can take months of diligent tracking and athlete monitoring. There is no one-size-fits-all approach, and these designations will change under different conditions such as dieting, the athlete's training age, and what phase of training plan the athlete is currently in. This can seem a bit daunting, especially if you are managing multiple athletes at a time. But the reward for diligence is a true evidenced-based approach to dosing training volumes in the most balanced way possible throughout the year. The Volume Landmarks provide a systematic way of answering the above dose-response questions.

- **Maximum Recoverable Volume (MRV)** is the highest volume of training an athlete can do in a particular situation and still recover to present a full overload in the next training timescale

- **Minimum Effective Volume (MEV)** is the lowest volume of training an athlete can do in a particular situation and still measurably improve

- **Maximum Adaptive Volume (MAV)** is the amount of training that, in any one unit of time, yields the greatest adaptive response

- **Maintenance Volume (MV)** is the lowest volume of training an athlete can do in a particular situation and still retain his or her abilities

If we know the Volume Landmarks, we can do some interesting things with our training programs. We can emphasize certain training components and deemphasize others without losing previously obtained fitness. Although the "jack of all trades" approach—whereby one trains all aspects of their sport in equal amounts at all times—is attractive to some, it leaves very little room for actual improvement in any specific area. This is because training all aspects of your sport at the same times leads to training volumes for each individual aspect that fall under Minimum Effective Volumes (MEVs) while simultaneously generating high systemic fatigue.

Being able to maintain your existing abilities with Maintenance Volumes (MVs) and really focus on one or two training components with Maximum Adaptive Volumes (MAVs) can provide substantial progress over time. This is actually the foundation of the Phase Potentiation training principle, which allows us to achieve high levels of performance by strategically sequencing our training components in concentrated blocks.

The Volume Landmarks can also help us think about how to more effectively manage acute and systemic fatigue. Training within our Maximum Recoverable Volume (MRV) allows us to prevent non-functional overreaching, as well as to strategically map functional overreaching periods. The Maintenance Volume (MV) can be used to develop active recovery strategies by reducing training volume periodically without fear of losing gains. Reducing training volume is one of the most effective ways of alleviating fatigue, and the Volume Landmarks provide a quantitative approach for doing so, without digressing your fitness progress.

One of our favorite applications of the Volume Landmarks in fatigue management is the exclusion of what we colloquially call “junk” or “garbage” volume. Junk volume is what many athletes unknowingly find themselves doing: training between their Maintenance Volume (MV) and Minimum Effective Volume (MEV). This means that they are training more than they need to in order to maintain fitness, but less than they need to in order to make gains. Athletes who fall into this trap accrue fatigue without any real increase in performance. Using Volume Landmarks enables athletes to discover how little training they can get away with without losing fitness, and more effectively periodize training programs.

Training within the Volume Landmarks, particularly within the Maximum Recoverable Volume (MRV), is critical to our discussion on recovery. Although many recovery strategies are useful and well documented, there is almost nothing that can make up for training consistently above MRV, making it a prerequisite step in developing fatigue management strategies. Too often, athletes are directed to try this drink, get this massage, perform this ancient ritual and so on, to enhance their recovery, when, in reality, what they need to do is go back to the drawing board and figure out how much training they can do and still recover from.

As mentioned, How Much Should I Train? offers a much deeper and broader discussion on MEV, MRV, and the other Volume Landmarks, including instructions on how to discover your personal Volume Landmarks, and handy worksheet templates for tracking them.

3 RECOVERY STRATEGIES

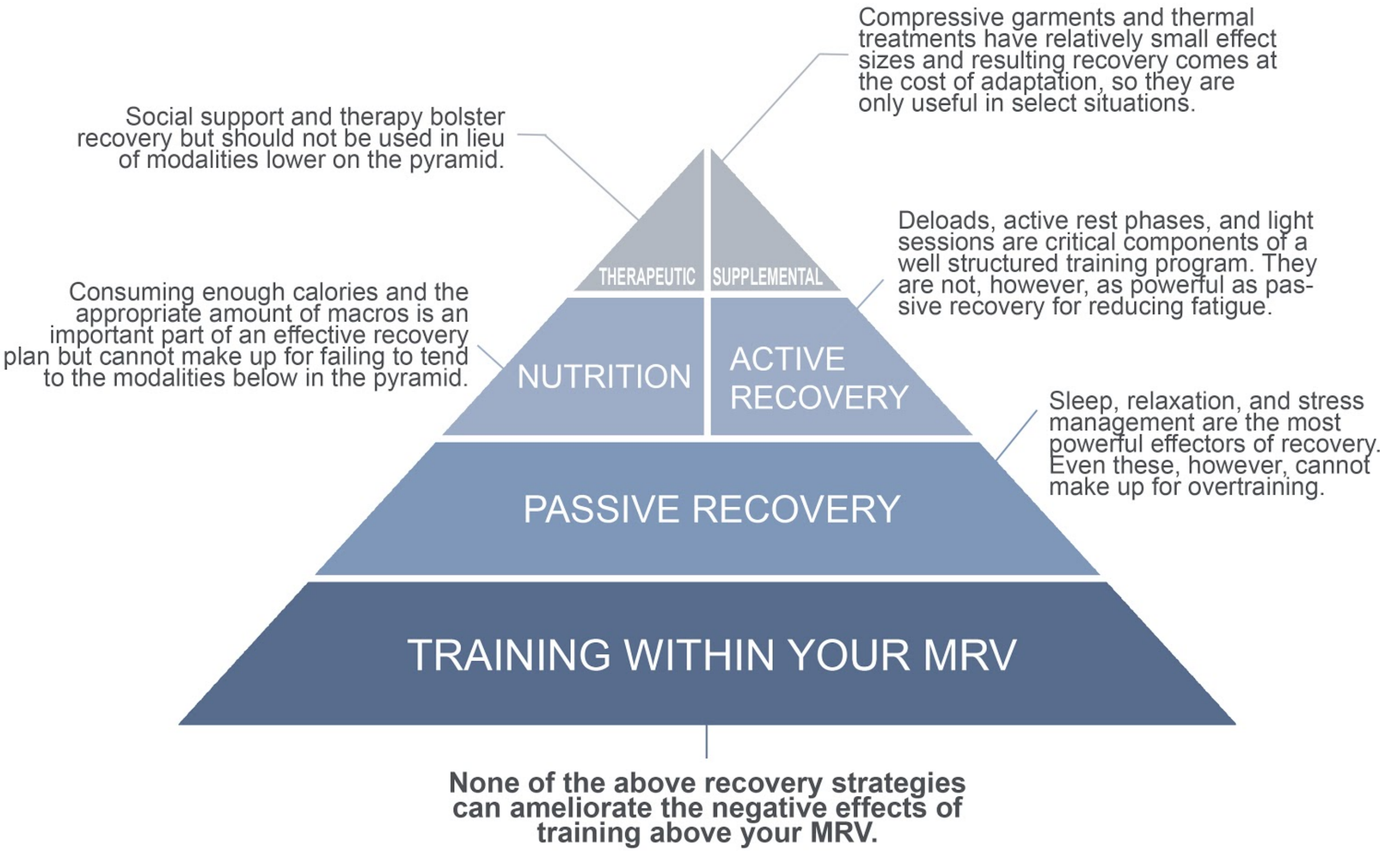
By allowing for productive training to continue for the longest time periods and at the highest levels, the best possible recovery makes for the best possible results. In this chapter, we'll explore the strategies that promote recovery from most to least effective, with later chapters focusing on the specific recommendations for each modality.

A recovery modality is anything you do that can help you recover. There are a number of recovery modalities that have a significant and practically meaningful effect on promoting recovery, and it is these we will focus on in the remainder of this book. While some of the 50 different potions and pills at your local supplement store might amount to a tiny recovery benefit, the act of spending money on them and even the very act of getting over to the store to buy them is likely to cause about as much stress as they are going to aid in recovering from. With that, let's look at some recovery modalities that don't come in pill form, but go a longer way.

Section 1: The Recovery Modalities

After an examination of the literature, we've nailed down five main recovery modality subtypes. We've also categorized them based on their relative impact on the whole recovery process. Figure 4 outlines our primary recovery hierarchy:

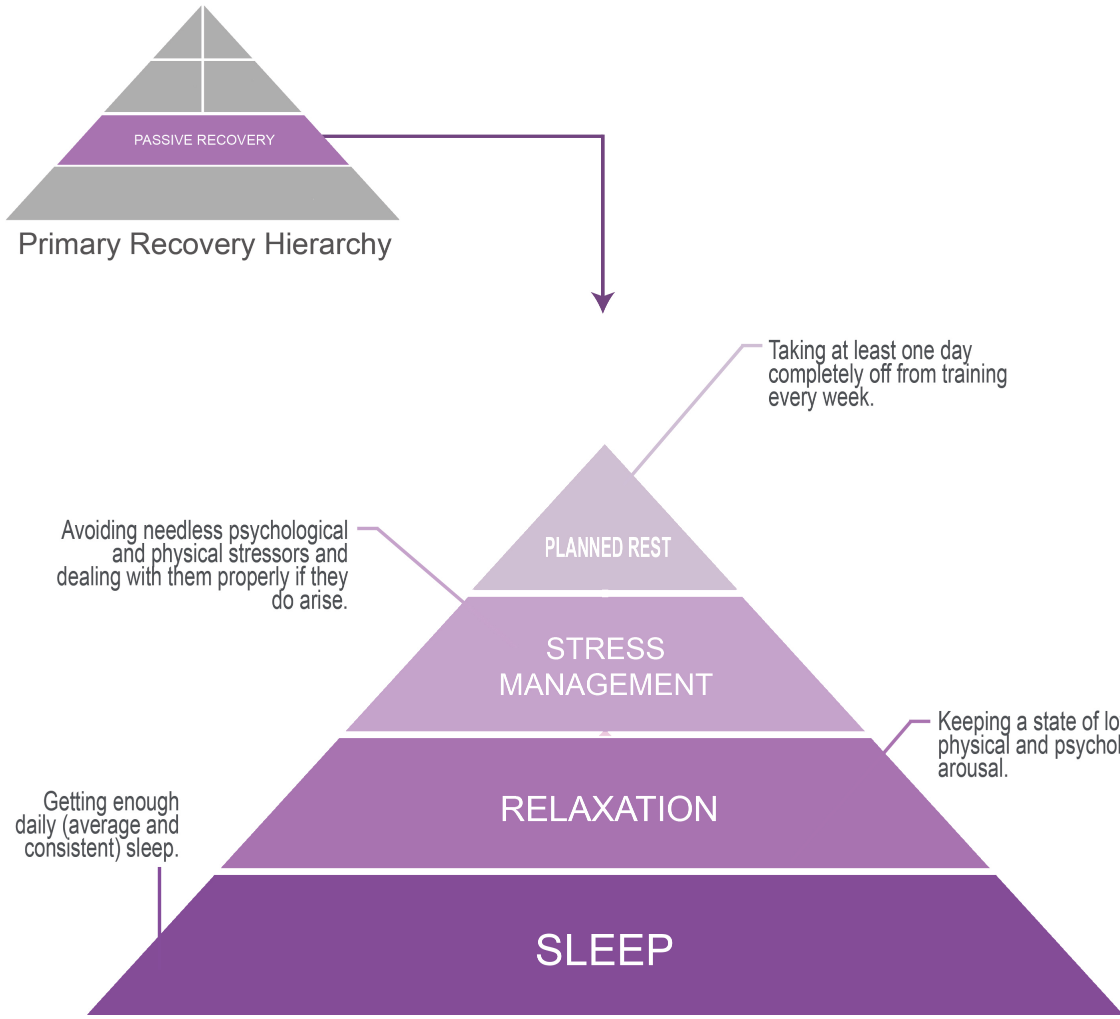
Figure 4: Primary recovery hierarchy



We've covered training within your maximum recoverable volume already, and as noted in the above figure, no amount of sleep or optimal nutrition can make up for training beyond your ability to recover. Sounds self-explanatory, but it's unfortunately all too common to see athletes training outside of their MRVs and trying to make up for this with ice and protein shakes, so it bears spelling out here.

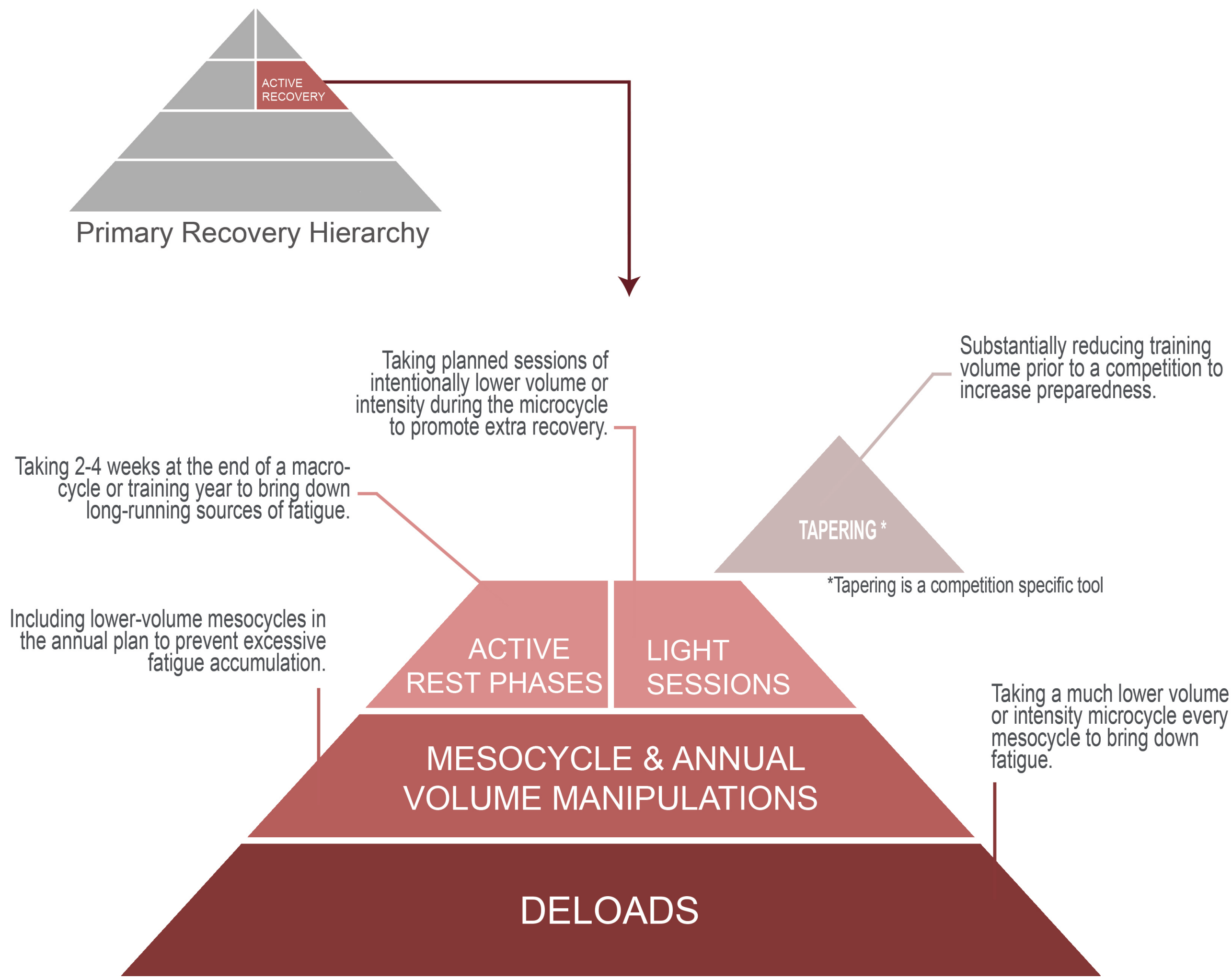
Passive and active recovery and nutrition are vast enough that they require their own pyramids, to rank their own subcomponents.

Figure 5: Hierarchy of passive recovery modalities



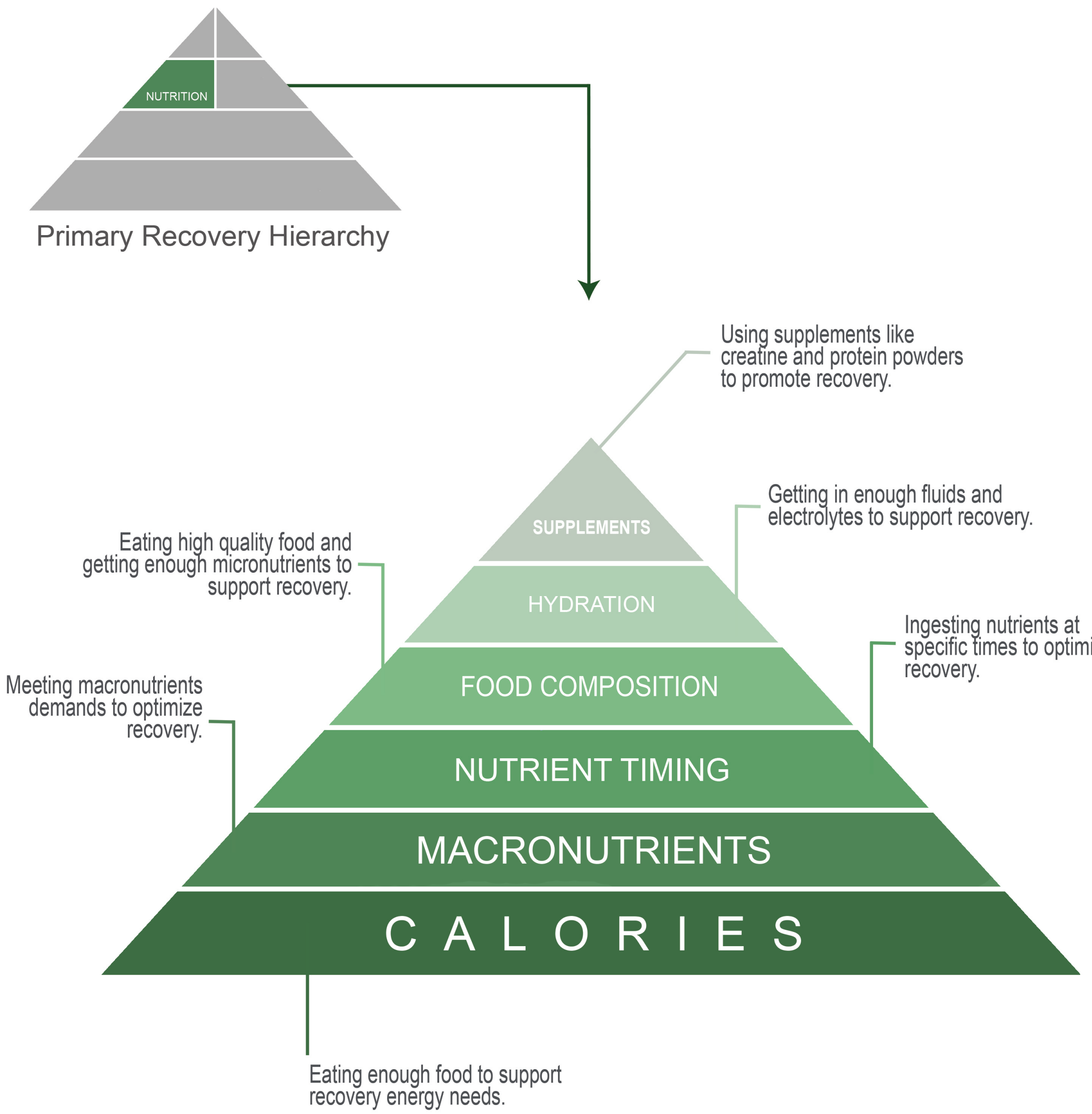
After training within your MRV, getting sufficient sleep is the next most important thing you can do to facilitate recovery. Sleep is therefore the base of the passive recovery pyramid. Maintaining a relaxed state during your waking hours is nearly as important. The less physical and psychological arousal you undergo on a daily basis, the less energy will be spent on getting back to homeostasis in these realms and the more resources you will have available for recovery. Related to this, and nearly as important, is keeping stress levels low in daily life. Finally, making sure to get in some planned rest—that is time you allot in advance to do things that facilitate stress management and relaxation—can also contribute meaningfully to recovery. Remember, although these components vary in importance relative to each other, they all comprise the second most important level in the main recovery modality pyramid: passive recovery.

Figure 6: Hierarchy of active recovery modalities



Once you are training within your MRV and attending to all of the passive recovery strategies, you can begin to focus on nutrition and active recovery modalities to further expedite your recovery. When delving into active recovery, considering within-mesocycle rest is your top priority. This means deloading from accumulation phases within mesocycles. Next on the priority list is tending to longer term adjustments in your training cycle, such as including lower volume mesocycles throughout the year. Finally, active rest phases and the occasional intentionally light training day are methods that can help alleviate mounting fatigue. At the top of the pyramid, tapering is a recovery modality that is specifically intended to prepare athletes for optimal performance at big games, tournaments, races, or other competitions. In this case, some adaptation trade-off may be made in favor of optimal performance, so this modality is not for use within the normal athletic training progress, but is key for optimal expression of developed fitness characteristics.

Figure 7: Hierarchy of nutritional factors for recovery



Equally important to active recovery, nutritional considerations contribute substantially to eliminating fatigue once the lower sections of the main recovery pyramid are tended to. For those of you who have read our books on dieting for body composition change, this pyramid might look familiar. Of course, in the case of body composition change, we're dealing with adding or removing tissue by manipulating calories and macronutrients. In the case of recovery, we seek nutrition that provides the needed energy and tissue-building-blocks (calories / macronutrients) delivered at the optimal times (nutrient timing) and in the best quality (food composition) to provide the body with tools for repair and recovery. Hydration facilitates the body's optimal use of these, and supplements add a tiny edge to your ability to recover.

Section 2: Modalities as Priorities

If best performance is your goal, maximum effort towards recovery is a prerequisite. Unless you live in a training camp where all of the recovery modalities are taken care of for you day in and day out, the resources you have to put towards exploiting the recovery modalities are inherently limited. Most athletes work within realistic limits of time, money, interpersonal relationships, commitments, and equipment access. Making trade-offs is a normal part of navigating the training and recovery processes because it's rare that we can have it all.

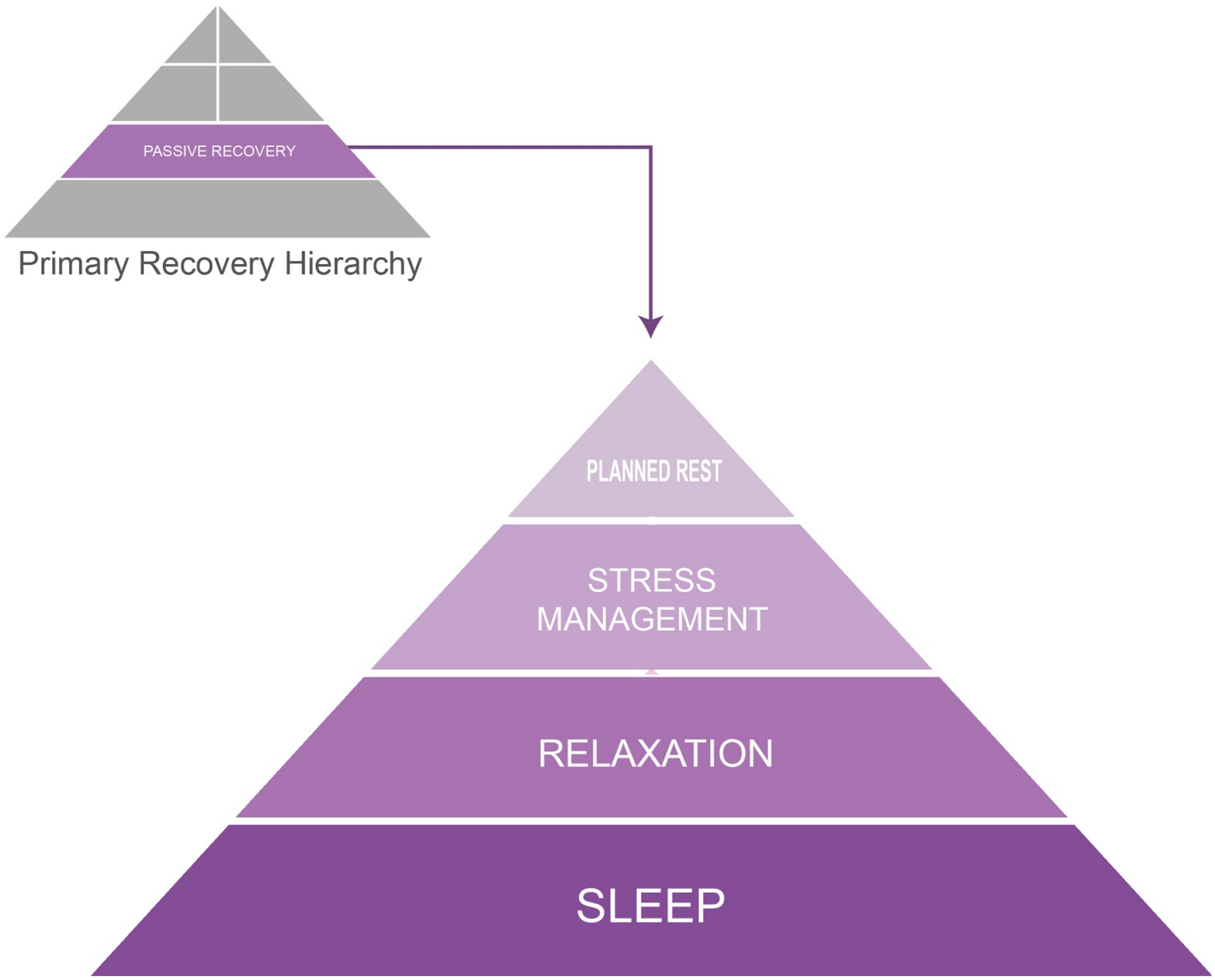
Given these normal limitations, it's wise to pay the most attention to the most impactful recovery modalities first, as presented in Figure 4 (primary recovery hierarchy) earlier in this chapter. If you spread yourself evenly over all of the modalities, irrespective of their importance, you'll get a good result, but not the best possible one. Likewise, if you were to prioritize a less important modality like hydration and took every step to optimize it but did so at the cost of tending less to other more important modalities, you'd net a very small percentage of your potential recovery. On the other hand, if you instead put that effort towards a more important modality, like sleep, by tracking and optimizing your sleep patterns, you'd net a huge fraction of the benefit of all of the modalities, because sleep is so critical to recovery.

Because the modalities can be ranked by their order of effect, it pays to invest most heavily in the big factors, and just make sure you aren't grossly violating the smaller ones. If you're just starting to think about how to improve your recovery—and thereby your performance—your best bet is to get good sleep and plenty of food, along with reducing your volume and intensity of training when fatigue gets too high. Once you've got a good handle on those basics, if your training and lifestyle are stable, you can move on to the details of stress management, therapeutic methods, and supplements. It's tempting to focus most of your efforts on hydration, supplements, and light sessions, since these seem sexier and take less planning. The problem with prioritizing these is that, since these modalities have less impact on alleviating fatigue, you'll be spending a whole lot of effort to get very little recovery in return. Additionally, this effort can be added stress and itself impede recovery, so the effect is compounding!

When we explain how to use all of the recovery modalities in great detail in later chapters, keep their relative importance in mind and try to focus on how to best employ the major ones before you consider the others.

4 PASSIVE RECOVERY STRATEGIES

When most of us first start to think about enhancing our recovery practices, our first thought is generally something like: “What can I *do* or *use* to improve my recovery?” While this proactive approach is usually commendable, because the foundation of our recovery road map starts passively, our first step may be as simple as finding ways to slow down. Passive recovery is a broad category of recovery methods that occur without significant physical or psychological effort. Instead of using energy or resources to dissipate fatigue, passive recovery relies on preventing the use of resources for other endeavors so that they can be routed towards recovery. In other words, passive recovery is the prevention and mitigation of fatigue via managing stressors, controlling levels of psychological arousal, and optimizing conditions for the body’s normal healing processes. As a reminder, Figure 5 is shown again below, ranking the relative contribution of passive modalities to recovery.



The passive recovery methods are without a doubt the most *powerful and universally applicable tools* in our recovery toolkit. There is no amount of methamphetamine, pre-workout powder, compressive garments, carbohydrate, or vitamin supplements in the world that can allow you to bypass the need for sleep and relaxation. A recovery program without passive recovery methods is like a training program without overload, which is to say quite ineffectual! Its importance notwithstanding, this recovery modality category is consistently under-applied in the real world in favor of sexier options like cryotherapy, fancy recovery drinks, or even the latest recovery trend or scam being peddled. Some of these trendy options might not work at all and even the best of them do not hold a candle to the recovery power of passive modalities. The irony of this is not just that athletes tend to forego their most powerful set of recovery tools in favor of less potent ones, but also that any of the observed benefits from less powerful methods are actually confounded by passive recovery itself. In other words, though Epsom salt baths by themselves have no measurable effect on fatigue reduction, relaxing in a warm bathtub *is* a form of passive recovery and *that aspect of the action does promote recovery.* So, in this example one could conclude that salt baths facilitate recovery when in reality the only aspect that contributed to this outcome was the fact that relaxation was achieved. Another common real-life example of this misattribution is massage, by which coaches and athletes have lived and died for years. Believe it or not, the research on massage suggests it has no significant effect on general physical recovery. It does, however, improve psychological well-being. In short, massage is likely beneficial for recovery simply because it gets the athlete to put down the phone, close her eyes, and fully relax, allowing body and mind to go from aroused to relaxed states.

As you read about any recovery strategy, both inside and outside of this book, here are two great questions to ask yourself:

- How is this method different from passive recovery?
- Are the results achieved by this modality likely just due to relaxation?

When reading about a new recovery modality, the gullible angel on your left shoulder will say: “This is great—you should try it!” But the skeptical sport scientist devil on your right shoulder will be saying: “There’s no additional benefit to this beyond relaxation! Why waste time or money on this when you could take a nice bubble bath or read a book instead?”

With that, let’s take a deeper look into the components of passive recovery and why they are so dang important.

Sleep

We all know the importance of sleep in maintaining a healthy lifestyle. Getting enough high-quality sleep is equally important in recovery from training. Unfortunately most athletes (and people in general) still don’t allocate enough time to sleep despite knowing its value. Sleep is the single most powerful recovery tool there is, and it comes with some awesome perks: it’s free, requires minimal effort, and all you need is time. Let’s discuss what it is about sleep that makes it so powerful.

What it is

Sleep is a progressive and orderly change of consciousness, muscle tone, and sensory perception. It is heavily influenced by our circadian rhythms (biological clocks) and plays a major role in the recovery adaptive processes. It operates in roughly 90-120 minute cycles, progressing through various stages, each with unique physiological states and brain activity. These 90-120 minute cycles are typically repeated 4 to 6 times during a night’s rest. A good night’s sleep involves going through these cycles uninterrupted, and waking near the end of a cycle.

How it works

Sleep is a major regulator of autonomic balance. Though not fully understood, sleep is thought to restore immunological and endocrine function, increase parasympathetic activity, and enhance memory consolidation, among other benefits. Larger amounts of growth hormone can also be released during sleep than during wakefulness, and this is thought to aid in tissue regeneration.

Expected Outcomes

Sleep effects are more easily described via the negative outcomes resulting from inadequate sleep, as the effects of sleep deprivation are vast and well documented. Given these, we can assert that a sufficient amount of high quality sleep will help you avoid them, including:

- Reduced exercise performance
  Performance reductions can be seen in maximal and submaximal strength, time to exhaustion, maximal work rate, sprint speed, cardiovascular measures, and others.

- Increased catabolic state
  Unfavorable changes can be seen in blood cortisol and growth hormone concentrations, with increases in sympathetic activity and decreases in parasympathetic activity leading to potential muscle loss.

- Reduced immune function
  Reductions in lymphocyte and antibody concentrations leave the body more susceptible to infections. Additionally exercising under immunocompromised conditions can inhibit the ability to fight off existing infections, while perpetuating risk of further complications.

- Compromised psychological states
  Unfavorable changes can be seen in motivation, irritability, perception of fatigue, perceived exertion during exercise, motor learning and memory, motivation, and proprioception (note that reductions in proprioception are associated with an increased risk of injury.)

How to apply it

Sleep operates on a dose-response relationship with outcome, meaning there can be insufficient, optimal, and excessive amounts of sleep. Insufficient doses of sleep simply do not accrue enough of sleep's restorative effects, and can leave one with any or all of the aforementioned negative effects. Excessive sleep may sound odd, but too much sleep can actually lead to a state known as sleep inertia which is associated with drowsiness, feeling disoriented, memory loss, fatigue, and reduced motor control lasting about 15-60 minutes after waking. There is also a significant amount of variation in sleep needs from one person to the next, as well as variation in needs for the same person, depending on dynamic activity and stress levels. As such, the optimal sleep does is highly variable, but for the recreational athlete it seems to fall between 6 to 8 hours per night on a consistent basis. For more advanced and highly competitive athletes, about 8 to 10 hours per night, also consistently. See Figure 8 below.

Figure 8: Optimal sleep-recovery curves for recreational and competitive athletes

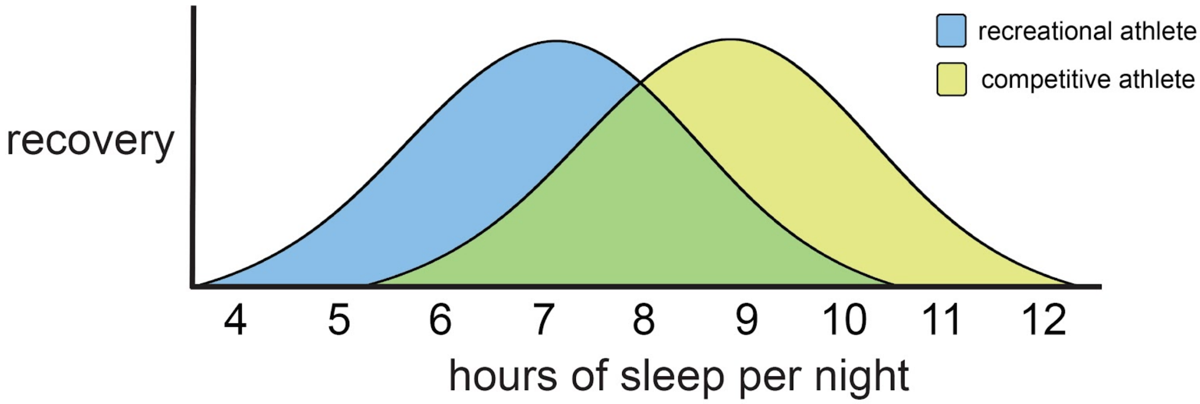


Figure 8. Qualitative bell curves of optimal nightly sleep averages needed by recreational (blue) and competitive (yellow) athletes is shown with relative expected recovery on the y-axis. The green area under the curves represents the overlap in these average nightly sleep recommendations for the two types of athletes. Most people irrespective of athletic level need somewhere between six to eight hours of sleep per night to recover from training. Harder and more frequent training necessitates more sleep to fully recover.

Besides quantity, we must also consider is sleep quality. A few relatively simple lifestyle and household modifications can help ensure better quality of sleep:

- Consistency, consistency, consistency. Having a consistent sleep schedule (going to bed at a similar time every night and waking at a similar time each day) will help you fall asleep faster and get higher quality sleep. Circadian rhythms are more regular when periods of sleep and wakefulness are consistent, a regularity that will help you fall asleep faster and to wake more easily. Develop a wind-down routine. About 30-45 minutes before planned bedtime, begin a routine sequence of events that always leads up to sleep. This can be grooming, having your bedtime meal, reading, quiet relaxation time, easy going shows or movies, a relaxing hobby, or any number of low-arousal activities.

- Avoid training in the late evening when possible.

- Avoid stimulants such as caffeine after all major training and work-related business has concluded. If training occurs in the evening, avoid using heavy amounts of pre-workout or other stimulants.

- Avoid alcohol in the hours approaching bedtime.

- Practice physical and psychological relaxation, like finding a comfortable position and progressively allowing all of your muscles from head to toe come to full relaxation. Allow your thoughts to wander freely and randomly and try not to problem solve or go over stressful aspects of your day. A common example of this practice is the use of meditation.

- Avoid watching TV, eating, studying / working, or doing any other activities besides sleeping or spending quality time with your significant other in your bedroom, and especially on your bed. Save the bed for sleep and “compassionate touch” (to be discussed later—do we have your attention now?)

- Keep the room quiet, dark, and cool.

- If you don’t fall asleep within about 20 minutes of lying down, get up and do something else for a little while. If you are unable to fall asleep within that time, it will just lead to more tossing and turning and low sleep quality. Read a book, stretch out a little, take a bath, and try again a little while later.

- Sleep in now and then, but remember the importance of maintaining a consistent schedule, and avoid over-sleeping and the effects of sleep inertia when possible. Naps may be helpful in supplying additional sleep benefits while maintaining a consistent schedule.

Special Considerations

One of the keys to maximizing the benefits of sleep is consistency, which in ideal conditions would mean sleeping roughly the same number of hours every night, as well as sleeping and waking at roughly the same times. Obviously, this is not always achievable and inconsistencies can compound for individuals with a non-traditional schedule, such as night shift work, rotational work patterns, travelling, and so on. In these cases, rather than focus on getting a consistent nightly amount, the goal is to maintain a consistent weekly average. Just as fatigue can accumulate day to day, so too can the need for sleep. As long as roughly 8 hours a night is achieved on average throughout the week, you’re still doing fairly well in the sleep arena, despite these non-traditional conditions. What that means is, if someone gets only 5 hours of sleep on night one, he or she may benefit from having a 10 hour session on night two, and a 9 hour session on night 3 to maintain that 8 hour per night average. Using the weekly average can be useful for offsetting inevitable sleep disruptions.

Naps are a fantastic supplement to sleep, but should *not be used in lieu of getting sufficient nightly sleep*. Naps are not as powerful as getting multiple, full, uninterrupted sleep cycles, but likely aid in similar ways, albeit at a smaller magnitude. Naps have been shown to positively influence daytime psychological arousal level, alertness, sleepiness, and memory. Naps can be used to provide extra recovery throughout the day on particularly tough days, or when inadequate sleep has been had. Again, the goal is to achieve adequate nightly sleep as a priority and then supplement with naps on an as-needed basis.

Naps also operate on dose-response relationships, but on a much smaller scale. The typical optimal dose of napping appears to be around 20-30 minutes, with less than that being insufficient to provide any revitalization, and greater than that typically allowing you to drop into deeper sleep phases, which results in grogginess, sluggishness, and sleep inertia upon waking.

There are a couple of special considerations for naps that don't quite apply to sleep. One strategy that the authors recommend is using stimulants like caffeine immediately prior to nap time. Having a coffee or an energy drink immediately before taking a nap can help you wake easily after 20-30-minutes, refreshed and eager to go. Another thing to keep in mind is that the short duration of a nap can lead to the temptation to continue sleeping past the optimal timeline. Having that caffeine right before and setting an alarm to ensure that you wake up on time are helpful ways to prevent descending into sleep inertia.

Now that we've inspected how sleeping helps recover throughout the unconscious portions of our day, we're left with the waking two thirds of the day and the stressors accumulated during that time. Next, let's look at how to reduce fatigue when we are conscious.

Relaxation

Relaxation is to day time what sleeping is to nighttime, making it another heavy hitter in our recovery toolkit. In fact, as briefly alluded to earlier, the authors speculate that relaxation is not only one of the most important recovery tools, but is also the reason that a variety of other recovery modalities have an effect. In a perfect world, every athlete would spend every waking non-training moment in a state of relaxation, minimizing physical and psychological efforts. In the real world, most of us have jobs, families, and a variety of other commitments, so there are some significant practical recovery hurdles facing non-professional athletes. In our experience, many coaches and athletes dismiss the idea of promoting relaxation as lazy, unscientific "kumbaya" nonsense. The joke is unfortunately on them and the athletes they train, as skipping relaxation will have them missing out on a massive potential recovery benefits.

What it is

For the purposes of our discussion on promoting recovery, relaxation can be summarized as the process of bringing an athlete from a heightened state of physical and psychological arousal to a state of physical and psychological calmness.

How it works

As physical and psychological stressors accumulate throughout the day, they typically induce varying degrees of stress responses, such as increases in sympathetic nervous system activity (the fight or flight system) and circulation of stress hormones such as cortisol, epinephrine, and norepinephrine, all of which can inhibit or blunt the recovery-adaptive processes. Relaxation can not only help reduce the active stress responses, but can also activate the parasympathetic nervous system (the 'rest and digest' system) which directly stimulates recovery and adaptation.

Because the parasympathetic activity aids in digestion, which can lead to improvements in protein and glycogen synthesis.

Expected Outcomes

Typical outcomes from relaxation can include:

- Decreased heart rate and blood pressure
- Decreased respiration
- Decreased metabolic stress
- Decreases in circulating catabolic hormone concentrations
- Decreases in catabolic cell signaling / increases in anabolic cell signaling
- Improvements in mood and affect
- Decreases in anxiety
- Decreases in perception of fatigue and tiredness

How to apply it

There are an abundance of direct and indirect relaxation strategies available. As discussed earlier, recovery strategies sometimes come packaged as exotic or “miracle” tricks and treatments, but their positive effects are often just a byproduct of relaxation.

Direct relaxation practices are straightforward and can be thought of as dedicated times to minimize physical and psychological efforts. It’s as easy as it sounds—just try to avoid doing anything stressful for a set period of time. *Indirect relaxation* methods are those in which a dedicated activity is promoting relaxation, such as breathing techniques and meditation. In the latter case, the techniques themselves may or may not have any direct merit, however, if they successfully enable the athlete to relax, this is arguably much more important. It’s sometimes said that there is a science to training, and an art to coaching. It’s very easy to ride our scientific high horse and dismiss what appear to be silly, foo foo methods, but at the end of the day, the coaches who find a way to get their athletes to relax, no matter how silly the method, will produce better performance by way of enhanced recovery.

Since relaxation practices have to be more strategically placed within the confines of our schedules, if your free time for relaxation practices is limited, the two absolute best times to schedule these would be:

- In the immediate two hours post exercise
- During a planned hour or so wind down routine before bedtime

It cannot be overstated that when it comes to relaxation and recovery, more is better. These times will provide the biggest bang for your time crunch buck. Relaxation performed immediately after training can help reduce catabolic stress and stimulate some of the more time sensitive aspects of anabolism. Relaxing before bed can help reduce our physical and psychological arousal levels, and allow for a quick and seamless transition into sleep, our most beneficial recovery modality. At the very least, even if you can’t hit the recommended times in particular, seek out 45 to 60 minutes of planned relaxation time once all of your major daily obligations are fulfilled. During this time, avoid anything that may cause additional stress, such as checking emails, taking phone calls, work, chores, planning, and the like. Instead, take those 45 to 60 minutes do whatever it is you want to do.

Now, you might be wondering, what types of activities can we do to promote relaxation? There are certainly a lot of choices! Some may seem obvious, while others are things you may already be doing, but never really thought of as a “relaxation activity” per se. Here are some examples:

- Sitting or lying in a comfortable position
- Eating a meal
- Reading your favorite book or graphic novel
- Watching TV or movies
- Listening to music
- Recreational socializing via phone, text or chat
- Playing video games
- Using breathing techniques
- Meditation
- Some forms of Yoga
- Spending time with friends, family, and pets
- Sitting by a fire
- Playing an instrument
- Hobbies
- Sensory deprivation chambers

As sport scientists, we’re usually inclined to instruct people to do simple things, like sit on the couch, eat a post training meal, and watch tv for an hour, but there is no reason to feel limited to these recommendations, as plenty of others can also elicit a similar relaxation effect. Similarly, anyone who has worked with youth, high school, and college athletes know that asking them to sit, do nothing, and relax is akin to telling Bruce Wayne he would better Gotham more by using his wealth and talents for philanthropic and humanitarian efforts than by punching criminals as Batman: good luck! This again is where the art of coaching comes into play, and if the athletes don’t comply with direct relaxation strategies, they might be incentivized by indirect ones, such as the opportunity to hang out with friends and have a meal.

Special Considerations

It’s important to remember that relaxation is the daytime equivalent of sleeping, and although not quite as powerful as sleep itself, should also be a major priority for athletes. As advised, any recovery modality should be held up to the light of questioning whether it’s somehow different from just spending time relaxing. As an informed athlete and individual, it is a good idea to ask yourself a few questions before buying into any allegedly therapeutic technique or treatment. First, is there enough scientific data to conclude that the strategy has a positive effect at all? If so, what is the mechanism by which the strategy causes this effect? If relaxation promotion is the real effector for a fancy recovery treatment (as it often is), your schedule and budget will thank you for skipping it and finding a “low-fi” way to accomplish the same state of relaxation in the comfort of your home, your gym’s sauna or even your office during lunch hour. On the other hand, if the fancy treatment package really optimally facilitates your relaxation, the fact that it may be unscientific or oversold is secondary to the fact that it works for you. The goal is to enter a state where recovery can occur—what gets you there is entirely your choice.

Even in cases where recovery modalities work by a non-relaxation related mechanism, we would argue that relaxation is still a contributing factor to the recovery achieved. Better established recovery methods like ice, compression, and hot baths have a distinct temperature or compression related benefit, but at the same time, these treatments necessitate the athlete sitting or lying down and doing nothing for a while, so may to some degree confound the results by adding the potent recovery power of relaxation. Perhaps more appropriately, those treatments serve as an avenue for initiating relaxation while simultaneously providing their distinct benefit.

Within this very large central concept of relaxation we also have the additional sub-consideration of planned rest. Although this largely operates in the same manner as general relaxation, it does carry some additional practical significance.

Stress Management

Mental stressors can elicit the same fight or flight and catabolic stress responses that physical stressors can. Likewise, when these stress responses are active, the anabolic recovery adaptive responses are blunted, resulting in reduced adaptive and or recovery potential. So, not only are psychological stressors unpleasant, but they can also manifest as physical effects when left unabated. Steps must be taken to reduce anxiety and emotional stress so as not to interfere with the training and recovery processes, though often easier said than done.

Psychological state is a related but distinct matter, as it affects how you handle all aspects of your life and experiences, not just the stressful ones. Your psychological state is your general outlook on life and feeling about yourself and your circumstances and abilities. We all have the personal experience of feeling insecure, defeated, or sad, and know the impact this can have on sleep, drive, and stick-to-itiveness. Likewise, when we are feeling fantastic, capable, and confident, these feelings make tasks seem more surmountable, allow us to sleep easily, and foster motivation to succeed. Not surprisingly, correlations have been found by research between stress levels and blood pressure, attitude and sport performance, or social support and life span—just some of the data that delineate a connection between mental state and physical outcomes. Our stress levels and our emotional/mental states impact just about everything in our lives, either directly or indirectly. Importantly, recovery from training is no exception.

What it is

Stress management is the practice of managing emotional responses and related physical and psychological efforts, or simply put: not getting too worked up or letting things get under our skin. Typical discussions on training and recovery revolve around managing physical stressors, which unfortunately leaves out the significant impact of psychological ones. Just as physical stressors can influence training and accumulate, so too can psychological stressors, the summation of which can have us finding ourselves overreaching much sooner than anticipated.

Psychological modalities for promoting recovery can include tapping into inherent temperament traits, like a naturally positive outlook, or characteristics built through directed personal development, like self-efficacy, motivation, and resilience. Factors that promote feelings of confidence, support, and acceptance can also contribute to recovery. These include the presence of a supportive family, friends, and coaches, therapists, and even pets—who and whatever furthers an individual's healthy, positive mental state.

How it works

In order to maintain autonomic balance and not shift into a net stressful catabolic state, we must incorporate stress management into our relaxation strategies. By ensuring a calm state and not allowing emotional arousal to escalate out of control, we can help prevent premature overreaching and can continue to maintain the intensity and volume of the training regimen.

Whether or not the psychological state has a direct physical effect on recovery is not entirely clear, but what is abundantly clear is that is has a *critical indirect effect* on an individual's recovery via modalities we have already discussed. In other words, feeling great and being mentally healthy would not in and of itself help you get through a rough peak week, but the secondary effects of those feelings can contribute substantially. A healthy mental state enables:

- Good Sleep
- Increased motivation to adhere to a training and recovery plan
- Increased ability to recognize and accept physical fatigue and take appropriate action
- Decreased accumulation of mental fatigue
- Decreased propensity for minor injuries

These factors in turn all contribute to an individual's capacity for recovery.

Expected Outcomes

We have already discussed the extremely important effect that sleep and stress have on recovery. Psychological state has a profound effect on both sleep and stress levels, and thus indirectly plays a critical role in recovery. Adhering to a well-planned training program with organized recovery strategies also requires a stable mind, and a substantial level of motivation. In turn, that adherence will make for better recovery. Further, when an athlete has the confidence and perceived support to not only adhere to his or her training program, but to stay flexible and take light days when fatigue is accumulating, even better recovery will result. Athletes who might tend to overtrain to prove themselves under conditions of low support and feelings of low self-efficacy will fare worse with respect to recovery, and thereby have decreased overall performance. Even putting extreme cases aside, a stressed mental state can lead to suboptimal body movement which can lead to the accumulation of minor injuries or damage; over time this can sap those precious resources that facilitate physical recovery.

How to Apply it

The idea of controlling your emotions is a bit of a misnomer, as emotional responses are chemically driven, and therefore mostly involuntary. While we may not be able to control our emotions, with stress management strategies, we can certainly control our behavior. Stressful situations will inevitably occur in life: somebody might flip you off on the road on the way to work, your significant other might be upset with you, your dog might eat your homework, and the list goes on. Ultimately, how much of that baggage you allow to cause you stress and anxiety is largely a conscious choice, and learning to let go is a skill that can be practiced and improved. Stress management is the process of choosing what stressors you focus on and which you let go—organizing your brooding efforts in a productive way rather than allowing sadness, anger, or frustration to consume your daily life. You cannot choose when you get upset by something, but you can choose whether to stay upset or move on, at least with practice.

Building a network of supportive friends and finding a good coach (if you are active in a sport) are excellent ways to tend to your psychological well-being. In addition, developing an internal locus of control (the feeling that your own actions influence all outcomes in your own life) has been shown to increase confidence, self-efficacy, and motivation. Striving to keep your ego in check and recognizing when you need to stop and manage fatigue also prevents you from creating psychologically-based, but physically-expressed roadblocks to your recovery capacity.

Special Considerations

While mental state is obviously very important to all aspects of your life, scientifically speaking, it is not the direct effector of physical recovery. Someone dealing with depression can make use of other more directly effective modalities such sleep, nutrition, and taking scheduled rest, and physically recover very well from training. It is simply that these feats are more easily done in a positive mental state.

Having a generally healthy, positive mindset may also contribute to an individual’s ability to—you guessed it—enter a state of relaxation. Feeling stressed or insecure can inhibit one’s ability to go from mental rumination and arousal to relaxation: another example of how the positive effects of relaxation can often be a confound in interpreting the results of recovery modalities.

It is also worth noting that some research does suggest a direct link between psychological state and physiological outcomes, but it is difficult to disentangle the psychological variables from the changes that result from them (such as alterations to sleep quality). Let’s take an example here to help make sense of this, and of the difference between correlation (two things occurring together or one after the other) and causation (one thing causing the other to happen). Noisy neighbors might ruin good sleep, but we cannot say that noisy neighbors are the cause of bad recovery—they just interfere with something that promotes it. Likewise, we cannot say that being hard of hearing in this example promotes recovery—the hearing deficit would prevent the noisy neighbors from waking you and interfering with your sleep, but would not itself be the source of recovery.

Another caveat here is that research on psychological effectors of physical recovery also generally looks at injury recovery as opposed to recovery from training, and it is unclear how much can be assumed from one about the other.

Planned Rest

There is a huge spectrum of training frequency tolerance from person to person. Much of the variance can be explained first by one's training age (how many years they have been training), and next by their training activities. Although many athletes can train at very high frequencies, all athletes should generally strive to achieve one to two days of planned rest per week.

The idea of planned rest is very simple: no structured training activities. This means no scheduled chalk talk, no lifting, no technique, no scrimmaging, or anything being prescribed by the sporting staff. This does not mean that the athlete must be locked away at home doing direct relaxation all day (though we certainly wouldn't discourage it)! No structured training simply means that the athlete can do whatever he or she wants within some reasonable boundaries. Professional MMA fighters will consistently mention that they "just needed a day outside of the gym". Instead, they may prefer to go out shooting guns, riding ATVs, taking some light hikes, hanging out on the beach, checking out that new bar or restaurant that opened in town, etc. These all constitute planned rest.

For obvious reasons, ideally we don't want our athletes doing a lot of physical exertion on planned rest days, but there is a significant need to have enjoyable, low stress, non-training days. One of the biggest benefits in planned rest is in psychological fatigue management. Structured sport training is a huge grind and takes a substantial psychological toll. The monotony of constantly needing to train, eat, sleep, and relax in a structured pattern can begin to wear on even the most dedicated athletes. Sometimes just knowing that another training session, however light, is coming up is stressful, requiring us to go through mental and physical preparation as well as creating anticipation anxiety while we wait for it to roll around. Additionally, taking time off, especially when exertion is low, can allow for glycogen stores to refill and give damaged tissues more opportunity to heal accumulated trauma.

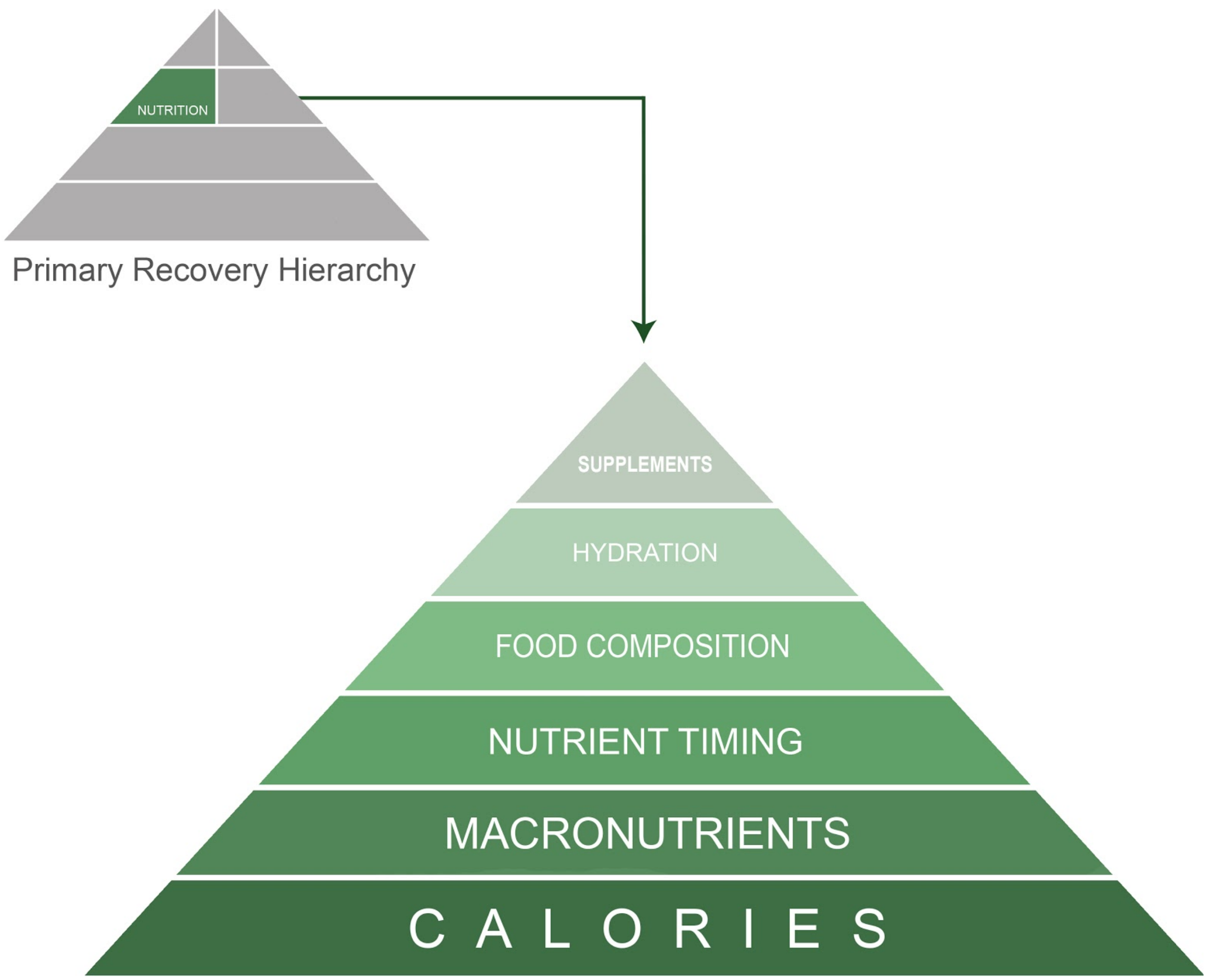
Training age may also dictate the necessity for planned rest. The homeostatic disruption generated when beginners train is inherently low, and they can get away with taking no planned rest days or as few as one per week to start (though, while not be devastating for the beginner, it's still undesired from a fatigue management perspective). Intermediate and advanced athletes, on the other hand, can generate a substantial amount of disruption during their training sessions, and typically require 1-2 days of planned rest per week, in addition to an increased need for active rest phases throughout the year (to be discussed in later chapters).

Combining these practices of sleeping, relaxing, managing stress, and making time for planned rest puts us on the shortest path to recovery. It bears repeating that passive recovery methods must be the primary concern before pursuing any additional recovery methods: before you can be active, you must first master being passive.

What is clear is that the passive recovery modalities should be the number one priority for athletes who aim to leverage the benefits of recovery in their performance. So, instead of asking which new toy or special drink will make us better, athletes should first look at their lifestyle and evaluate how aptly they are structuring it so as to best facilitate the rigors of their training.

5 NUTRITION FOR RECOVERY

When we say that diet in general promotes recovery to a large extent, we don't mean that all features of one's diet are of equal importance. In fact, aspects of diet range from being enormously impactful on recovery to having effects so small as to be detectable only with scientific experiments. In addition to the asymmetrical effect of various features of diet on recovery, it's also worth mentioning that nutritional changes that promote recovery are not always the same ones that are recommended for optimal body composition changes or performance. That's right, if body composition or performance are your goals, your optimal diet plan will differ from one optimized for recovery. While this difference is not drastic, small shifts will favor one outcome over the other. If recovery is a priority, nutritional adjustments can be made to that end without completely disregarding nutrition for body composition and performance and vice versa. As a reminder, Figure 6 is shown again below, ranking the relative contribution of aspects of nutrition to recovery.



You might recognize the aspects of this pyramid as similar to the diet priority list for body composition and performance from some of Renaissance Periodization's earlier works The Renaissance Diet and Renaissance Woman. While the order of importance of these diet features is similar for both recovery and body composition or performance, the effective quantities and recommendations that go along with some priorities differ considerably. Let's take a look at the first and most important dietary factor for recovery: calories.

Calories

While calories make up around 50% of the importance of diet for weight changes and performance, they make up a much larger portion of the recovery-focused diet. We estimate that calorie balance may account for 60-70% of recovery success. Thus, calories are the most critical aspect in a diet's effect on recovery.

There are two basic explanations for the impact of calorie considerations on recovery. Most fundamentally, the actual processes that recover your body from hard training are literally powered by the energy provided by the calories you consume. Secondly, eaten food, the amount of which is measured by calories, also composes the building blocks of the damaged components of our bodies that are replaced and upgraded during recovery. In other words, your training-battered body needs to be rebuilt, and consuming requisite calories results in the availability of both the energy and the building blocks needed for that repair.

The preeminence of calories in recovery is confirmed in scientific experiments, but can be observed in everyday examples. If you played sports in high school, you may recall that the average high school athlete's attention to the details of nutrition is unimpressive at best. Some all-too-typical examples of the kind of eating you see in teenage athletes includes:

- Not eating breakfast, or replacing it with a large soda or energy drink
- Having a bag of chips, an ice cream sandwich, and a soda for lunch
- Not eating an after-school snack and going straight to practice
- Stopping for fast food on the way home after a hard practice
- Otherwise subsisting on a diet of mostly of candy, burgers, cereal, and "pizza rolls," (which scientists have concluded are neither pizza nor roll)

Believe it or not, the negative effects of the above-described diet are very small in the grand scheme, so long as one condition is met: at least enough calories to maintain body weight are consumed. This means that so long as sufficient daily (or at least weekly on average) calories are taken in, recovery can, for the most part, proceed unhindered. If you were involved in high school athletics, you may recall schools hiring clinical nutritionists to give lectures on proper eating to the sports teams. While everything presented made sense, the star athletes would often be in the back of the lecture hall, eating potato chips and drinking soda, goofing off instead of listening to the speaker. Would they have been better athletes had they paid attention and implemented the recommended strategies? No doubt. The fact that they were already standout athletes without employing such strategies (so long as isocaloric conditions were met) demonstrates the importance of calories to the recovery process. Research studies confirm the above observations: when sufficient calories are consumed, recovery is, to a great extent, promoted.

In fact, the more calories the better for recovery. Within a wide margin, the most recovery-promoting state is the hypercaloric state, wherein more calories are taken in than used for daily needs. A hypercaloric state does, however, lead to weight gain, which is not always optimal for your body composition or performance goals. This makes perfect sense from an evolutionary perspective: when calories are in excess, the body is not as stingy about passing them out for non-essential-survival processes, like recovery. Recovery is then promoted even further than it would be in an isocaloric environment.

In general, the more food you eat, the faster and more completely you can recover. Outside of possibly Sumo wrestling, there are probably no sports in which a chronic hypercaloric environment is conducive to performance and body composition demands. This puts athletes who seeks performance, recovery, and a lean body composition in a conundrum. They need to eat as many calories as possible to recover as well as possible, but, many times, the body composition and performance goals dictated by their sport render this unrealistic. While they can't eat a hypercaloric diet at all times in the name of recovery, they can use this knowledge about the importance of calories to shift between eating for recovery and for performance and body composition in a real-world sport setting:

When Recovery Needs > Need for Body Composition Changes

If recovery is your priority, and your body composition is well within parameters, eat hypercalorically. If you're competing in a weight class sport next month and you are very light for your class, let's say 4kg below the weight cutoff, should you try to stay isocaloric? You don't want to get excessive and gain the whole 4kgs, as this would throw off your performance. Being just slightly hypercaloric might mean you gain 2kg—a body weight change that in most cases will not significantly affect performance—which keeps you well within your weight class, but allows you to greatly improve your recovery ability. Some athletes get so caught up in dietary perfection that they needlessly exclude the option of a recovery-promoting hypercaloric environment.

If you don't need to lose weight or fat, stay away from hypocaloric periods as much as possible. Similar in nature to the prior example, those athletes who don't need to lose fat or weight at the present time should very much avoid hypocaloric dieting. Yes, it's tempting to sink into a hypocaloric phase here and there to get leaner for aesthetic purposes, but if you're already lean enough to perform close to your best, the cost of a hypocaloric state to your recovery abilities may not be worthwhile. Whether it be during regular training, times of emotional stress, travel, or any other scenario, your recovery will benefit greatly if you make sure to avoid dips into hypocaloric conditions. If you have to choose, overeating for a few days is likely better for your recovery than undereating for that length of time. A prime example of this is the detail oriented traveling athlete. Some very meticulous athletes pay very close attention to nutrition and when they travel, they may find their food choices highly suboptimal compared to their usual intake. Many such athletes will eat much less than their current calorie demands require, under the pretext that they "don't eat junk food". While a concern about food quality is valid, eating enough calories is better than avoiding less healthy food options by not eating anything: five donuts is much better than no food at all for recovery. So, unless body composition is *far and away your number one priority*, you should highly consider calorie needs as a first priority in any suboptimal nutritional situation. For recovery, eating *anything* is almost always better than eating nothing at all.

When Recovery Needs = Need for Body Composition Changes

If you have to lose fat, but need to prioritize recovery as well, achieve weight loss with as many calories as you can and plan ahead so that you can lose at a slower pace. In many athletic circles, dieting for fat loss means quickly dropping the athlete's food intake to abysmally low levels. These drastic reductions certainly result in weight loss, but also have disastrous effects on recovery (not to mention unnecessary muscle loss). Many a sport culture is guilty of this practice, including gymnastics, dance, ballet, weightlifting, MMA, Jiu Jitsu, and powerlifting. Dieting for fat loss will always be a trade-off of performance and recovery outcomes for body composition changes. Ideally the negative effects on any of the traded outcomes can be minimized by moderation in execution of the desired outcome. When planning your cutting phase, give yourself enough time to lose the weight at a reasonable pace that doesn't needlessly risk recovery, performance, or excessive muscle loss. Usually, losing around 1% body weight per week or less is the moderation needed in weight loss to prevent serious decrements in performance and recovery. When you start cutting, eat as much food as you can while still keeping your target weight loss pace. In cutting, there's no gold star for those who needlessly rush the process or needlessly suffer—in fact these practices may prematurely induce metabolism and hormonal changes that will make weight loss more difficult. By dieting slowly as needed, more food can be consumed through the diet and more recovery benefit, muscle mass, and performance abilities can be retained.

Lose weight in your macrocycle when you don't need recovery at its macrocycle-best. It would be great to have optimal recovery at all times, but, because you can't support a hypercaloric diet at all times, you have to choose when during your macrocycle you want to promote recovery over body composition optimization. For example, if you're cutting weight for a weightlifting meet, and losing actual fat tissue, not just water, that cut is going to be hypocaloric and cost you some recovery ability. When is the best time to do this cut from a recovery perspective? The answer is as far away from the competition as is possible. In the weeks of the taper leading up to the competition, and especially during the competition itself, missing lifts can be catastrophic. During such tapering and competition times, you want to maximize your recovery, so that you have the best chances of hitting your goals at the meet. Even in the month or so before the competition when your lifts are getting heavier—recall that intensity is very fatigue generating—you will need calories for recovery and progress to continue. Thus, when cutting for weightlifting or any other strength and power sport, you're better off doing it nice and early in the offseason, when you can most afford to take the hit in, among other things, your recovery ability.

Macronutrients

After calorie balance, the macronutrients providing those calories have the next most important effect on recovery. It is the ratio of carbohydrate, protein, and fats consumed that dictates what building blocks are available and at what rate they can be digested and used to repair your tissues and facilitate recovery. The individual macronutrients have varying levels of importance, which we will now discuss.

Carbs

Of the macronutrients, carbohydrates have the largest effect on recovery within the realm of dietary interventions. Hold on a second, did we mean to say protein? No, this is no typo: carbohydrates do have a greater effect on recovery than protein! Replenishing lost carbohydrate stores not only provides the raw energy substrate needed to perform at high levels during subsequent exercise, but also optimizes cellular conditions to drive anabolism. When we say carbs have an effect on “recovery,” we mean that depleted muscle glycogen stores have to literally “recover” their used-up carb stores from dietary carb intake.

Interestingly enough, carb intakes also suppress stress hormone release, so carbs can also promote psychological recovery as well as physical. If recovery is your number one priority, getting your carbs should be second on your diet to-do list, right behind getting enough calories.

How many grams of carbs do you need per day in order to recover best? That depends largely on three factors:

- Your body weight (more specifically your muscle mass)
- Your volume of training
- Your daily activity levels

Because it’s your body systems that use the carbs, the size of those systems (how much lean muscle you have and so on) is a big factor in how many carbs you need to eat to promote maximum recovery. While this fact alone doesn’t allow us to make any numerical recommendations with regard to carb intake off hand, it does tell us that, when we see carb recommendations for recovery, we need to look for relative (per-body weight) values and largely ignore absolute values.

This is an important point. When reading an assortment of literature on recovery, you’ll run into carbohydrate recommendations to optimize recovery. Be wary of figures given in absolute terms, such as “50g post-training” or “400g per day”, and search instead for relative figures such as “1g carbs per lb of body weight.” If you simply employ absolute values without any additional customization, you’re likely following intake recommendations intended athletic conditions and body types of the study from which such values were derived, which may differ significantly from your own needs. As you might imagine, a 300 lb athlete generally needs a great deal more carbs for recovery than a 100 lb athlete. When looking at all of the literature on carbohydrates and recovery, more than 90% is of that research is done on endurance athletes. most of whom weigh around 155 lb. If you simply employ the absolute values for folks of that size, you might be undereating or overeating carbs by vast quantities in relation to your personal parameters and recovery needs.

Now that we know we’re looking for relative-scaled values, we can begin to look at the second factor in recovery-carb needs: training volume. The amount of work you do takes a certain amount of ATP, and most ATP production requires carbohydrates. Thus, the volume of physical work you perform on any given day has a very close correlation to the amount of carbs you’ll need to eat that day, so as to begin replenishing what’s being used, and thereby recovering for your next session. What this implies is that even larger athletes with smaller workloads might not be consuming as many carbs per day as smaller athletes with higher workloads. While much more exact recommendations can be explored in the cited literature, some generalizations can be drawn with respect to carb intake averages and sport and training demands. These are outlined in Table 2 below.

Table 2: Daily carbohydrate intake recommendations for recovery from sport training

DAILY CARBOHYDRATE INTAKE RECOMMENDATIONS FOR RECOVERY FROM SPORT TRAINING

Sport Training Duration	Carbohydrates per lb bodyweight
< 1 hour	~1 gram
~2 hours	~2 grams
3-4 hours	~3 grams
4+ hours* *or 2+ hours high level endurance training	4+ grams

A quick caveat to this framework is that athletes who train very hard (2 hours plus most days of the week), may need to consume higher levels of carbohydrates even on low activity days, to fully replenish their glycogen levels for the next several hard days of training. The muscle damage of chronic high-intensity and high-volume training can impede muscular glucose uptake and glycogen synthesis to some extent, and thus requires compensation in the form of higher carb consumption during both training and non-training days.

Outside of that caveat and perhaps some other edge cases, the volume of training is closely prescriptive for the amount of carbs the athlete will need to recover. So long as adequate protein and fat is consumed, and calorie levels remain desirable for the current goal, more carbs than recommended can be consumed for the benefits of a caloric surplus. Undereating carbs far below the recommended quantities, on the other hand, will almost always result in compromised recovery, so erring on the side of a bit more carbs is good practice when recovery is a high priority.

This general framework implies that while larger athletes who are throwers, weightlifters, powerlifters, and strongmen may need to eat quite a high absolute amount of carbs, their relative carb intakes might not be overly impressive on account of their lower training volumes. On the other hand, while high level endurance athletes tend to be on the smaller end of the body size continuum of all athletes, they may eat some of the highest absolute carbs quantities, simply to fulfil their exceptionally high relative daily carb quotas.

While we eat carbs with the intention of filling our glycogen and blood glucose reserves for athletic performance, those reserves are not only used to fuel athletic performance. Just about every daily task requires energy from carbohydrate reserves, from doing homework or writing up that work report, to doing dishes or walking the dog. If you don't account for how much total work you're doing in respect to your carb intake, you'll risk under-eating carbs for your sport needs, as the carbs you need for sport will need to be shared with those needed for all of your other daily tasks. In general, we would recommend allotting up to an additional 1g of carbs per pound of body weight per day for higher energy-consuming daily activities outside of sport. This means that while a hard training endurance athlete might normally need 3g of carbs per pound of body weight per day to maximize recovery, the same athlete who takes a more physical job might then need 4g of carbs per pound body weight per day for his or her needs. In some rare situations, even more is needed. If you work highly manual construction for 8 hour shifts for example, you might need 1.5g in excess or even more. In any case, the numbers here are secondary to the principle: if you do a lot of daily physical work, you need more carbs than if you don't, regardless of what your training volumes are in your sport practice.

In addition to these numerical recommendations, we've compiled a short list of scenarios in which carb consumption guidelines are more practically illustrated:

Endurance athletes cannot mess around! If you train in a high level endurance sport (or any sport that has you doing intense training for 2 hours+ per day, such as advanced soccer, fitness sport, or basketball) you can't skimp on your carbs. The literature on low carb performance in high volume sports is mostly very dismal, and some of the promising literature (of which there is little) on decent performance in low carb states demonstrates the need for at least several weeks of adaptation to that lower carb state, during which performance is very depressed. If you're putting out a ton of volume in your training, err on the higher side for carb intake. If you think you'll be ok with just 400g per day in your situation, 425g probably won't hurt, and could likely help. High volume athletes who are carb phobic, or who think carbs make them fat (they don't, only excess calories do that!) may want to reconsider their position, to recover and perform at their best.

Strength and power athletes don't need super high carbs. This is not to say that strength and power athletes will somehow be harmed by high carb intakes: in most cases they will be just fine with such intakes. In fact, through most of the 80s and 90s, while almost all carb-need research was done on endurance athletes, many sports nutritionists had no issues communicating these needs to all athletes, with no changes or special considerations for athlete type. Thus, numerous throwers and weightlifters whose practices might only be 45 minutes of low-volume work on some days, were struggling to slam down hundreds of grams of carbs they didn't need, based on data gathered from endurance athletes. This often resulted in suboptimal fat and protein intake for those athletes, which were displaced by the large carbohydrate amounts prescribed.

Fat loss diets should avoid carb cuts as a means to reduce calories for as long as possible into the diet. Not only does cutting carbs needlessly impede recovery, it actually reduces the potency of the training stimulus so much that anabolic signaling is reduced and muscle loss is much more likely in the hypocaloric conditions in which such cuts are made. The more carbs you can eat on a cut, the more recovery and performance you'll retain, and the more muscle you'll end up with at the end of the cut. This can be done by cutting mostly dietary fats until their minimal levels are reached. Approaching a calorie-cutting diet by cutting carbs first may be psychologically rewarding, as carb cuts also reduce water retention in your tissue, so the scale—and perceived progress—move faster. But, while losing more water weight at the front end might look like progress on the scale, fat will not be reduced any faster, and might actually be lost at a slower rate, due to reductions in anabolic activity! As such, cutting carbs before absolutely necessary is a physiologically bad move for recovery, performance, and body composition.

Periods of high need for recovery benefit from higher carb intakes. If you're well within your weight range and calorie needs, upping carbs during high recovery periods is often a good idea. Times of such emphasis include the days and weeks before peak training cycles, during peak training cycles, and the recovery sessions and deloads that follow them. In the week or days that precede peak training, higher carb intakes can both preload the glycogen needed for such large efforts, and indirectly reduce some of the fatigue that's already accumulated before peak training begins. Because muscle damage has a suppressive effect on glycogen repletion, and because high levels of accumulated fatigue are associated with lower hunger levels, filling up glycogen stores *before* peak days and weeks might give you a better chance of high performance during those peak training times than would eating lots of carbs during those days and weeks. Of course that's not to say that eating high carbs during the peak times themselves is bad. In fact, it's quite necessary for being adequately "fueled", and keeping fatigue as low as it can be. After the peak, and especially days later, when muscle damage has mostly healed, higher carb intakes are wise, as they are needed to refill glycogen levels before the next period of accumulation training can begin.

Protein

Though outranked in importance in most recovery scenarios by calories and carbs, protein is also indispensable for optimal recovery, especially in the long-term. While carbs refuel on the order of hours and days for top performance, sufficient protein intakes supply the literal building blocks that replace worn out or damaged structures in the overloaded athlete's body. In addition, they provide the building blocks for enzymes used in facilitating many basic functions, including recovery and repair in all systems of the body. So, while lower than needed protein intakes are quite tolerable, and in fact difficult to notice on the order of weeks, months of under-dosing protein will increase the chance of chronically unhealed wear and tear to the tissues. If we think of carbs as having a quick recovery payout, we can think of protein as a long-term investment.

While it's important to understand that protein's role in recovery is secondary, its role in body composition is quite primary. So, most athletes will eat enough protein to support optimal body composition, and thus typically more than meet the protein needed for their recovery as a byproduct. As far as numerical recommendations, 0.75g of protein per pound of body weight per day is an intake level that is almost sure to supply enough amino acids for recovery purposes. Since more protein than that is needed to support a muscular physique, and even more is needed to support additional muscle growth, most athletes should seek to consume about 1g of protein per pound of body weight per day.

The only big practical recommendation with protein amount is to avoid protein excesses in the hope that you'll get some sort of additional benefits. When athletes find out that about a gram of protein per day maximizes muscle growth, some figure that 1.5 or even 2.0 grams per day must surely grow even more muscle. This is sadly not the case, so beyond about a gram per pound per day, protein availability is no longer the rate-limiting step of muscle growth, and other factors—such as intracellular signaling, hormones, and degree of training overload—dominate the equation. Now, there's nothing unhealthy or dangerous about eating that much protein, but within an athlete's given calorie goal at any time, more protein usually means less carbs, fats, or both, and too few of both of these macronutrients will start to cost in terms of recovery, body composition, and performance.

Fats

Of the macronutrients, fats are the least determinative of recovery ability. As long as you get in enough calories, carbs, and protein in that order, fat levels need only be present at certain minimum levels to support recovery. Without fats altogether, critical body functions will be impaired, and that of course indirectly impacts recovery. Outside of these mostly indirect links, however, fats don't support recovery in any serious or direct way.

Our recommendation for fat minima is around 0.3g of fat per pound of body weight per day. Less can be consumed if the focus is shifted to certain types of fats (essential fats), but at 0.3g, enough will be supplied for recovery and basic bodily function.

From a practical perspective, ensuring the minimum fat amounts in most diets is pretty easy. In fact, dropping under this minimum recommendation is a rather difficult endeavor, as physique competitors who've temporarily tried doing so in their final prep phase will attest. So long as your carb and protein intakes are being met, fats can be eaten to as high an amount as will fulfill one's remaining calorie needs.

Fat consumption is so easy, in fact, that there exists a small peril with fat intake that merits mention here. If most of the foods you consume are high in fat, you can quickly reach your calorie need levels without actually consuming enough carbohydrates or proteins. Endurance athletes are known for eating lots of food, but most of the foods they eat have tons of carbs and not so many fats. Typical endurance diets feature more foods like whole grain breads, pastas and cereals than they do foods like pizza, ice cream and cheeseburgers. That's not to say that such junk foods are somehow directly bad for the endurance athlete. The issue for those of us not clocking 20+ miles run per week, is that some of these foods have such high fat contents that getting enough carbs while staying within calorie constraints gets problematic when consuming them. The big takeaway is to focus on meeting carb and protein quotas first, and then "fatting it up" within your allotted calorie bounds.

Timing

Timing is not a huge concern for the recovery of the athlete, but it's big enough that it can make a difference in results, whether that means placing at an important race, or the aggregate long-term effects of paying close attention to nutrient timing through the mesocycles.

The most critical aspect of nutrient timing deals with when we ingest the most important of recovery macronutrients, carbohydrates. There are four important points to mention with regard to carb timing, and a point each for fat and protein timing.

Carbohydrate Timing

Intra-training carbs can benefit long-duration exertions. In high intensity activities that last longer than about an hour, the consumption of intra-training carbohydrate can promote recovery within the session itself, allowing for higher intensity output at the end of the session than would otherwise be possible. So if your training sessions last 1.5-2 hours or longer, consuming carbs during those exertions promotes performance throughout, by recovering some blood glucose and perhaps sparing the utilization of some muscle glycogen. This is a very small effect, but can be significant especially if multiple daily sessions are planned.

Post-training carbs can support multi-day sessions. If you train a lot, you're often splitting your training into two or even three daily sessions to train with higher intensities than you would be able to if all those sessions were condensed into one long one. By consuming carbs after training and in the interval between the end of one session and the beginning of next one later that day, a significant amount of glycogen can be restored and second-session performance is likely to be maximized. Yes, daily carb intakes are more important than this timing detail, but if you have insufficient or no carbs after your first training session, the intensity of your second session will not be optimally nutritionally supported. By consuming carbs between training sessions, you can best recover the most possible performance for the second session, and provide the most overload, netting better results on average.

More carbs should be consumed post-training. In the first four to five hours following exercise, your recently-trained muscles—the same ones you're likely to use again later that day if you train more than once—are much more receptive to the uptake of glucose from the blood than they are at any other time of the day. Post training carbs get digested and turned into blood glucose during this window. As the post-training period continues, this sensitivity slowly declines, with a return to normal several hours later. With this in mind, it's probably wise to consume most daily carbs in the post-training window in order to maximize glycogen repletion. For athletes training far under their MRV or those involved in low-volume pursuits, such timing is of minimal or no concern. The harder they train relative to their abilities, the more they train, and the more often they have multiple daily sessions, the more athletes need to be concerned with post-training carb timing for best recovery. High glycemic carbs also absorb faster and actually replenish glycogen more completely (even when equated in amount with low-glycemic carbs), so they are even better choices immediately after training.

Excessive single-meal carb amounts should be avoided. When a bolus of carbs (especially rapidly digesting ones) much in excess of 4g per lb of body weight is consumed all at once, glucose uptake and glycogen repletion processes can be overwhelmed, and some of those carbs might not be stored as glycogen in muscle but rather converted to fat, which is much less useful for recovery. If you consume a giant carb meal in the morning, no carbs for the rest of the day, train hard at night and go to sleep right after, you're likely to get suboptimal glycogen repletion. If you cannot eat most of your carbs in the meals after your training, spreading out their consumption evenly throughout the day is the next best option.

Protein Timing

Protein must be consumed regularly for best results. If a high amount of protein is taken in at once, only so much of it will be used for recovery and other athletically-interesting processes, while the rest will be burned off as energy. If you eat all of your daily protein in one meal and none at other meals, for example, you risk burning too much of it off as energy and under-feeding the athletically-relevant processes of recovery and muscle growth or maintenance that occur throughout the day and night. There is good scientific backing to suggest that an even split of your daily protein needs should be consumed about 4 to 6 times per day, or roughly 5 hours apart or less between meals.

Fat Timing

Fat intake should be avoided near the training window. Fats slow down the digestion of carbs. This can limit the amount of post-training carbs that are digested in time to take advantage of increased glycogen replenishment post-training. This can also mean prevention of maximum glycogen replenishment when only short feeding windows are available between training sessions. For this reason, fats should be limited in the post-training window, especially if another training is to occur later that same day.

How much do these factors concern athletes that only train once a day and perhaps not for long during that session? Not much. But athletes who train so little probably have few problems recovering in most cases anyway, being that they are likely to be under their Maximum Recoverable Volumes (MRVs).

Food Composition

While your calories and macros can come from a wide variety of foods, the exact kinds of foods they come from matters to some extent. Food composition is the variable that deals with the kinds of actual foods that comprise a diet, versus just the calories or macros of the eaten foods. Food composition applies to all three macro categories, and ranks all foods from each category in the following manner:

Proteins

Proteins can range from complete, easily digested protein sources all the way to incomplete, and difficult to digest sources. “Complete” in this context means “supplies all of the essential amino acids needed for human function” and “incomplete” means that one or more of these essential aminos occur in insufficient quantities to meet body function needs. Animal protein sources such as meats, dairy, eggs, and poultry are usually ranked close to ideal in completeness and digestibility, while plant protein sources such as wheat, nut, or bean sources are more often incomplete, and tend to be more difficult to digest. There are some complete sources of plant protein, such as soy, nutritional yeast, hemp seed, and mycoprotein, but many of these are still not absorbed as well as animal protein, due to the body’s inability to digest cellulose. The vegan athlete must be very mindful of this, and overshoot protein consumption a bit, to consume and absorb sufficient amounts. Processed plant protein can make complete sources of vegan protein more accessible as well, by eliminating cellulose.

Carbs

Carb sources are ranked based on their degree of processing. Vegetables, fruits, and whole grains that are unprocessed tend to be slower digesting and also tend to have higher concentrations of vitamins, minerals, phytochemicals and fiber than more processed sources. Very processed sources of carbs like white bread, sport drinks, and dextrose powder have almost all ingredients outside of the carbs themselves removed. Choosing the more quickly digested processed options around training times and sticking to the less processed at other times is ideal when considering food composition for recovery.

Fats

Fats are split into multiple types, which have differing effects on our physiology. While the effects of fats on recovery have not been directly studied, we do know that certain fats are necessary or better for our health, and health is a prerequisite for good recovery. Monounsaturated and essential polyunsaturated fats—Omega 3 and 6—are the ones your body needs most, and do the most to reduce systemic inflammation and other maladies. Saturated fats are relatively neutral in their effects on health and performance if consumed in moderation, while trans fats are generally deleterious to the body’s functioning.

Because health is both a prerequisite to and the most essential underlying aspect of recovery, the foods that best support it will form the basis of our nutritional recovery intervention. Thus, high quality protein sources like animal protein or processed plant protein, unprocessed veggies, fruits, whole grains, and healthy fats should account for the core 75%+ of the calories comprising a recovery-friendly diet. In addition, veggies, fruits and whole grains are high in micronutrients—vitamins, minerals, phytochemicals and fiber—offering additional health and therefor recovery benefits, which is all the more reason to prioritize their consumption.

That being said, there are times where more processed foods are advantageous. As mentioned, processed plant protein is generally healthier, in that the processing enables easier digestion of that protein. Likewise, during and right after training, a very fast digesting carbohydrate source like a sports drink or dextrose powder is ideal to prevent catabolism and kick start the recovery process. Another situation in which more processed carbs can be an advantage is when carb intake is so high as to be practically difficult to consume. For example, just to recover from daily training, 150 lb endurance athletes can be consuming in excess of 600g of carbs per day. Trying to consume that many carbs per day in only unprocessed veggies, fruits, and whole grains will often present two problems. The first is that such sources have a very high index of satiety: they make you fuller and this fullness last longer than more processed carbs. Thus, unprocessed carbs can fill you up so much, that eating high amounts of them can be nearly impossible to stomach. The second problem is that, because unprocessed carbs have so much fiber in them, trying to eat super-high carbs daily from just unprocessed sources may exceed safe daily fiber recommendations, and can cause a variety of problems ranging from nutrient loss to severe gastrointestinal distress. For athletes that need to consume large quantities of carbs, using a combination of processed and unprocessed sources is the most sensible practice.

For much more information on food composition and performance, check out our books [The Renaissance Diet] and [Renaissance Woman].

Hydration

Hydration is of course critical for health and even survival. Degree of hydration can even play a large role in your sports performance abilities. Though the body is very good at letting you know when to replenish fluids via thirst, its signals aren't always perfect, and can sometimes lag behind the need to hydrate during training. In order to promote recovery between bouts within a session, like between sets of exercises, fluids must be consumed within an hour before the training to establish proper hydration levels by the time you begin, and high fluid intake must be continued during training. It should be noted that your thirst response lags behind your dehydration by up to 30 minutes or more during intense training, so that you will have to drink fluids before and during training *before you actually feel thirsty*. You can use thirst as a good index of hydration in other times of the day that are not close to training. During training, however, it is best to preemptively consume liquids.

Hydration is important before and during training, but it's equally as important after training if you're training more than once a day. If you want to recover as much performance capability as possible, making an effort to hydrate right after your first training session is over and consistently consuming fluids in the interval between the two sessions can enhance your chances of recovery.

When hydrating, consuming electrolyte-rich fluids is more beneficial than consuming just water, so calorie free drinks that contain electrolytes in addition to water may be very beneficial in such circumstances. Though by no means a must, having electrolyte instead of just water for intra-training hydration can also help. And don't worry about electrolytes when consuming water throughout the day, because the food you eat will usually have more than enough electrolytes for your needs.

Recovery Supplements

If we had written this book about the most sought-after and googled recovery modalities, recovery supplements would almost certainly be the hot topic of our recovery discussion. It's very tempting to seek an easy pill or powder to aid with something so important as recovery. While it would be great if a couple of pills and some topical ointments could replace good planning, good sleep, and excellent nutrition, that's just not remotely the case. In fact, we'd go so far as to say that there's really no such thing as a "recovery supplement" in meaningful sense of the phrase. Some supplements can help recovery, but their effects are always disproportionately small compared with those that make up the base layers of our primary recovery pyramid (Figure 4). That said, let's briefly look at the six kinds of supplements that *can* help with recovery a bit.

Essential Fats

Essential fats are the fats our bodies cannot make internally, which thus need to be consumed in the diet. Most diets meet our needs for essential fats quite well, but supplementing with DHA and EPA fats—usually from fish oil but best in purified form—can guarantee that essential fats are never a limiting factor to recovery. Such fats also help reduce total body inflammation, which can considerably help recovery.

Multivitamins

As with essential fats, most balanced diets provide enough vitamins and minerals to support recovery, especially those that adhere to the ~75% high quality food composition recommendation. Taking a multivitamin can provide the insurance policy to make sure recovery is being met.

Whey Protein

By acting as a very fast digesting and super high quality protein source, whey protein can enhance post-exercise recovery and adaptation.

Carbohydrate Drinks or Powders

As mentioned in the section on food composition, sometimes rapidly and easily digested processed carbs can aid recovery. Carb drinks and powders help get carbs where they need to be when they can be best utilized in the training window.

Casein Protein

Casein protein is both high-quality and very slow digesting. When consumed at night before sleep, casein can provide the body with a steady stream of amino acids that can support both recovery and adaptive processes while you sleep, making it a great holdover for when we can't eat protein in 3-5 hour intervals.

Creatine

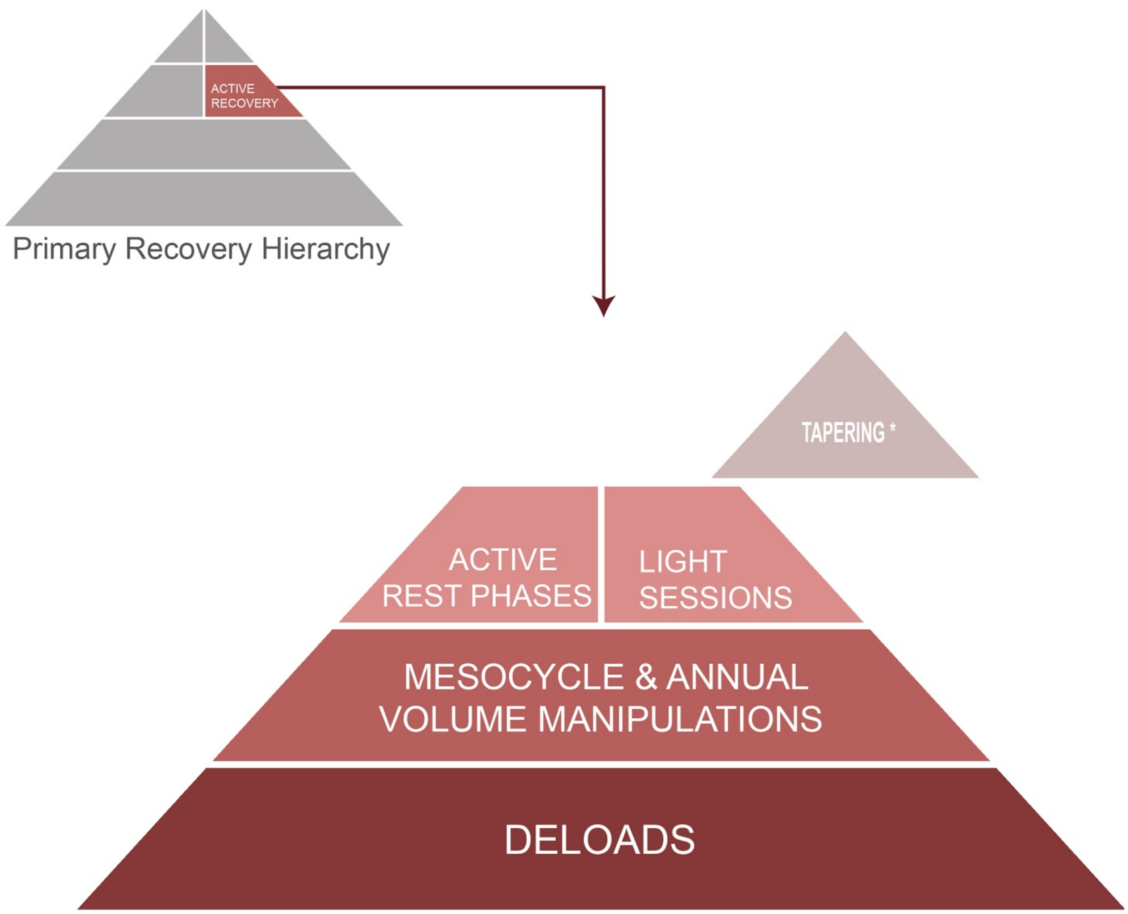
Creatine doesn't offer a whole lot of long-term recovery assistance, but it is perhaps the most effective supplement for within-training recovery. For example, if you've done 4 sets of 10 squats that were very challenging, creatine supplementation can perhaps make the difference between you getting another two sets of 10 at the same weight, or only getting 8 followed by maybe 6 reps on the succeeding sets. By boosting recovery between sets, creatine supplementation can allow for more high intensity work to be done. The great news here is that this raises the stimulus and thus potential benefits of training. The slight reality check, however, is that you'll have to make sure to be on top of your other recovery modalities to make sure you can actually recover from the now higher stimulus in training over days and weeks in the longer term.

All in all, supplements can help recovery to a very small extent. For individuals training and competing at a high-level, this slight edge may very well be not only worth it, but mandatory for staying competitive. For individuals involved in sport or training more recreationally, the effects of recovery supplements will, in most cases, go unnoticed.

It bears repeating here that, for beginners, intermediates, and advanced competitive athletes alike, no amount of supplements can make up for neglecting the fundamentals of recovery such as sleep, stress management, food intake, and intelligent program design. Supplements should be thought of exactly as their name implies: nothing more than supplemental to the other more powerful recovery modalities.

6 ACTIVE RECOVERY STRATEGIES

Our previous discussion on passive recovery methods focused on modifying lifestyle to accommodate the rigors of training, but we have yet to address modifying training in order to optimize recovery. Active recovery is a process of modifying training throughout microcycles, mesocycles, and macrocycles to periodically alleviate fatigue and potentiate long term gains, all while continuing to train. The “active” in active recovery refers to the fact that, by making the training modifications we will discuss, you can continue to actively train while simultaneously sufficiently recovering from your training. As a reminder, Figure 7 is shown again below, ranking the relative contribution of active modalities to recovery.



Although active recovery methods are not as powerful as passive recovery modalities, any properly designed program should include some, if not all, of these active recovery methods. As with every category of recovery, active recovery methods also observe a hierarchy of importance, where deloads and large-scale volume manipulations make up the base, while active rest and light sessions, though also important, are less critical recovery methods. What this implies is that programs not using deloads or large-scale volume manipulations are almost certain to eventually fail, whereas programs lacking in active rest phases or light sessions will be missing optimal fatigue management, but will continue to be sustainable. This is similar to our previous discussion on nutrition, where total calorie intake and macronutrients were given essential consideration in recovery, but timing, food composition, and supplements were all less impactful recovery tools.

Back to active recovery, let's first speak to the seeming paradox of how training can actually enhance recovery, when it's training that causes fatigue to accumulate in the first place! Though counterintuitive, there is a critical point between overload training and complete rest (when no training takes place) where activity reduces fatigue without allowing deconditioning. And, believe it or not, prescribed activity during this time can be even more effective than complete rest at reducing fatigue! Active recovery methods are additionally valuable in that they also allow for the continued enhancement of sport and training related skills or tactics, which complete rest forces us to take a break from enhancing.

Let’s take a deeper look into active recovery methods and how they work in the real world.

Deloading

What it is

A deload is a period of training (typically one microcycle in length) with deliberately reduced training volume. The deload is strategically placed after planned overreaching periods of training, in order to reduce fatigue and prepare an athlete for the next phase of training.

How it works

The deload takes advantage of training dose-response relationships. Because training volume is the most impactful variable in the accumulation of fatigue, in order to alleviate fatigue, volume must be reduced. However, if volume is reduced to below maintenance training volumes (MVs), deconditioning can occur. This can be circumvented by bringing volumes down to maintenance levels while sustaining a relatively high intensity. Doing so allows for substantial reduction in fatigue, while maintaining sport and training related technique and conditioning.

The deload is the mesocycle-scale approach to active recovery. Training at low volumes enhances blood flow to the muscles in need of recovery, and provides just enough stimulus to help trigger anabolic effects. This blood flow improves nutrient uptake and waste product removal. Additionally, because training volume during deload is at or near maintenance levels, it does not itself generate a significant amount of fatigue.

Expected Outcomes

Deloading provides a variety of physical and psychological benefits. Typical outcomes of the deload can include:

- Reduced perception of fatigue
- Recovery of exercise performance
- Reduced joint and muscle pain
- Healing of accumulated microtrauma
- Replenishment of glycogen stores
- Restoration of autonomic balance
- Restoration of endocrine (hormonal) balance
- Renewed motivation for further training

How to apply it

Deloads should be applied after planned overreaching phases, which for most athletes means once every 3-6 weeks. For sports with a season, deloads are typically planned in the preparatory phases, when training is more voluminous, instead of during the in-season phases.

Although there are a number of different ways to go about structuring a deload, their universal requirement is a reduction in training volume. This means the number of sets and reps, distances traveled, and time spent training must all be substantially reduced. This applies to all training types, not just weight training. For athletes who have identified their volume landmarks, the deloads should be programmed at maintenance volumes for each respective phase. For athletes who do not know their landmarks, volume reductions should be substantial. This reduction should typically be that of 40-60% of training volume used immediately before the deload, or by roughly *half* of normal overload training. In the weight room, this can come from a reduction in sets and reps. For instance:

- If the previous training was 4 sets of 8 reps in the squat for a total of 32 reps, then the deload could be two sets of 8 reps, or even 4 sets of 4 reps, totaling 16 reps.
- Volume decreases can be as simple as shortening training sessions. If normal rugby practice was 2 hours, deload rugby practice would be 1 hour.
- On the other hand, intensity is reduced only marginally during the deload. Reductions of about 10-15% of the relative intensity are commonly used, as these are still generally within the necessary intensity threshold to prevent deconditioning.

For specific examples of deloads and their use in strength and physique sport check out our earlier book [The Scientific Principles of Strength Training.]

Mesocycle and Annual Volume Manipulations

One of the base tenants of periodization states that, if we expect to make progress, we can't train at the same volume and intensity all the time. This also holds true in fatigue management and recovery. High volume training throughout the year can be very useful in driving the adaptive processes to their maximal potential, but doing so both generates high amounts of fatigue, and lowers our ability to express other fitness characteristics. Although the latter may only be applicable to sporting populations, the former applies universally.

Imagine trying to drive a car where the only way to propel it was by flooring the accelerator. You'd get around fast, but both wear and tear and the odds of getting into an accident would increase disproportionately, to the detriment of the machine. Just the same, we can't always be "flooring" our training volume to make progress. To minimize accidents, we recognize that there are times to go slow, times to go fast, and *a lot* of time spent somewhere in between. Strategically manipulating our training loads throughout the year can help us not only stay productive but also minimize our chances of injury and non-functional overreaching.

What it is

Mesocycle and annual volume manipulations, as the name implies, refers to the periodic alteration of total training volume from all sources throughout the year. For physique sports and general fitness, volume mostly consists of hypertrophic and work capacity training. In these cases, the manipulation of volume would include periodically reducing the number of total sets and reps within the mesocycle. An athlete who did a three month weight cut would likely pair this with hypertrophy training. Subsequently, taking a lower volume, strength or resensitization phase afterwards would help reduce the physical and psychological fatigue from months of training while dieting. The lower volume phase would also potentiate further gains in subsequent mesocycles, by resensitizing the athlete to high volume training.

Mesocycle and annual volume manipulations for sport training differ from those used in physique training. Manipulations of this kind are, in theory, intuitively incorporated into a well-periodized sport training plan, though many coaches and athletes don't realize how these changes relate to fatigue management. Changing volume (and intensity) throughout the training plan allows the athlete to phase potentiate fitness over time, and also ensures that the fatigue generated is not interfering with the athlete's ability to express the fitness characteristic(s) they seek to overload. Most coaches know that, to achieve power and speed, the athlete must first establish a base of work capacity, then develop strength characteristics, and then eventually transition into direct power and speed training. What many do not know is that the fatigue generated by work capacity and strength training is actually the factor that prohibits the expression of power and speed during the earlier training phases. So, while this training structure does alleviate fatigue and thereby improves performance, it's helpful to know that this is the mechanism by which it does so.

Different fitness characteristics have different MRVs, and, in order to train and express each, volumes must be adjusted accordingly. Endurance sport training aside, hypertrophy and work capacity training generally have the highest MRVs of all fitness characteristics. The fatigue generated by this type of training would prohibit the expression of maximal strength, power and speed. In order to train those effectively, the training volume must be reduced within the MRVs of those respective fitness characteristics. So, for a typical strength and power sport, we would initially see very high training loads in the general preparatory phase, then a progressive decrease in total training loads as they transition into specific preparatory and competitive phases, and likely the absolutely lowest values during a taper (an extreme reduction in volume to facilitate performance, which we will discuss shortly). Thus, for sport training, periodization allows us to achieve these volume manipulations throughout the year, not only to manage fatigue, but also to phase potentiate.

How it works

Large-scale volume manipulation works mostly through the same mechanisms as deloads, but on a much larger time scale. You can think of deloads like a weekend: a short break after a hard week's work. But, as we all know firsthand, sometimes those two days off just aren't enough to recharge us physically and mentally. That's when you need to cash in on a 1-2 week vacation. You can't vacation all the time because you need to work, but, when you finally take one, it can really help you drop the accumulated stress baggage you've been carrying around for some time. Larger scale volume manipulations are like that annual 1-2 week vacation, facilitating active recovery.

Expected Outcomes

Most of the benefits of mesocycle and annual volume manipulations will parallel what was described in deloads, however there is a unique benefit to these manipulations due to their larger time scale. Because training operates on dose-response relationships, there is a desensitization effect from doing chronic hard training. In other words, one can reach a point where they are habituated to their training loads, making their body less responsive to them. This is commonly experienced as staleness, plateauing, or feeling “flat”, resulting from the athlete overload training without making observable progress. In addition to the aforementioned active recovery benefits, taking lower volume training phases throughout the year can positively influence the sensitivity of cellular regulators of anabolism.

In addition to alleviating perceived fatigue, large-scale volume manipulations can also be crucial in preventing or addressing burnout, a lack of motivation or desire to train.

How to apply it

Application of this technique will vary depending on the sport or activity, but will operate similarly across the board. For the sake of ease, we will compare this method when training for physique or general health versus advanced sport training.

Training predominantly for physique and health involves hypertrophy-style high volume weight training. With the exception of beginners, athletes who train for hypertrophy during phases of weight gain or weight loss see the greatest benefits at increments of 2-6 months. After 2-6 months of high volume training, intermittent lower volume phases can allow resensitization and time for recovery. A resensitization phase is a deliberately low volume training phase paired with maintenance dieting, wherein the athlete is training at extremely low maintenance level volumes. A similar effect can be achieved by using a strength phase, which is roughly two thirds the volume of a standard hypertrophy phase, with increased training intensity. Although both resensitization and strength phases provide resensitization, the key difference between these is that strength phases additionally provide overload training for strength development, and allow for fitness to progress rather than merely be maintained. Though resensitization does not provide an overloading stimulus for strength, it provides a greater decrease in volume, potentiating bigger impact for later high volume training phases.

From a strict training-only perspective, these phases can be as short as 4 weeks (or 1 mesocycle) to achieve the desired effects. However, when paired with dieting for stabilizing body weight set-points, this is usually extended. The length of this phase should be at least two thirds of the time spent dieting up until immediately prior to when weight stabilization is initiated. If the athlete did a 12 week fat loss and hypertrophy training phase, the weight stabilization and resensitization training phase would need to last 8-12 weeks or longer. Unfortunately, this can add up to a substantial amount of time without real overload training. To balance these competing priorities, a combination of using resensitization followed by a strength phase can help ease the individual back into normal training without spending too much time without progressing. Similarly, the use of other techniques such as a minicuts can provide a similar, though perhaps not as powerful, benefit of fatigue management and resensitization. Although the technical details of minicuts are not within the scope of this book, the article “All About Minicuts” by Dr. Israetel details their mechanisms and implementation.

With the exception of endurance sport, most strength and power sports follow a similar pattern of training leading into competitions. Here is a simplified example of how these transitions flow:

Hypertrophy / Work Capacity → Strength → Power / Speed

Hypertrophy and work capacity phases will contain the largest training loads for that annual cycle. During the following strength phases, volume must be brought down to accommodate increased intensity, but remain within MRV. In a similar manner, when progressing from maximal strength phases to power and speed phases, volumes must be reduced again. This is because without such a reduction, strength volumes would blunt the expression of power and speed needed to overload those characteristics.

Structured sport training is already designed to effectively manage MRVs. The difficulty in determining individual volume landmarks is the wide spectrum of fitness characteristics and training modalities. Typically, it is recommended that athletes not train the same fitness characteristics for more than 3 mesocycles in a row. After 3 mesocycles, athletes should strongly consider transitioning to a new phase for variation and fatigue management purposes. After long stretches of work capacity training, a single strength mesocycle can go a long way in reducing fatigue and potentiating further gains. Likewise, after long stretches of strength training, a maximal strength phase or power phase can elicit this same effect.

Special Considerations

It is important to remember that these large volume manipulations are very useful in reducing fatigue while keeping the athlete active, but there is a balance to strike between generating and then managing fatigue. Spending copious amounts of time recovering through resensitization and maintenance phases comes at the cost of time spent training. If one finds oneself in a position where deloads are inadequate and low volume phases are required for recovery every other mesocycle, this athlete is most likely exceeding his or her MRV. No amount of active, passive, or nutritionally-based recovery methods can mend this problem other than the reevaluation of one’s MRV.

Active Rest

Active rest phases are one of the most well-known forms of active recovery, having become integral to sport training long before its merits were widely appreciated. Like many things in sport and exercise sciences, the effectiveness of active rest was later validated by research, which now give us a deeper understanding of its role in managing fatigue.

What it is

An active rest phase is a period of unstructured training, wherein the athlete can engage in any form of training they desire. But, compared to planned rest, where the athlete has no minimum of training or activity, active rest does require that they do some training that meets the following criteria during this phase:

- Maintain a reasonable body weight and body fat content
- Maintain lean body mass
- Maintain basic cardiovascular and muscular work capacity

Active rest phases are typically implemented after long increments of arduous training or competition. Under these circumstances, stress levels can be very high and recurrent burnout is a common problem, especially if the athlete did not perform to their own expectations. When stress levels have peaked, active rest becomes crucial, though is useful in a variety of circumstances, ranging from those of extreme stress to normal levels. Have you ever gone to the gym or to practice, only to be sickened at the very thought of training? Even though you approached the session with the intention of training, subconsciously, you have no desire to train. This state can even have psychosomatic manifestations, such as increased heart rate, blood pressure, nausea, and diarrhea. When your body's subconscious needs are in such discordance with your conscious training intentions, active rest is a critical intervention.

How it works

The effects of physical healing from active rest phases parallel those of deloads, most significantly surrounding the psychological alleviation of fatigue. In addition to the intense physical demands of training and competition, accumulated psychological stress can escalate into more serious problems. Some very common symptoms of psychological stress from training can include:

- Burnout
- Reduced determination
- Demotivation
- Reductions in confidence and efficacy
- Mood swings and erratic or inappropriate emotional responses
- Sleep disturbances
- Anxiety
- Feelings of helplessness

Many of these symptoms can arise simply from stress accumulation and overreaching, however it has also been suggested that some of these feelings are exacerbated by a lack of autonomy, meaning that the athlete feels that her prosperity in sport is outside her control. Active rest phases seek to address these issues, by reducing physical stressors through reduced training volume, reducing psychological stressors by breaking the monotony and rigorous structure of training, and re-establishing the athlete's sense of autonomy. We can easily understand how having someone telling us exactly what, when, and how much to eat, train, and sleep every day could wear on our sense of self.

Active rest offers a holistic recovery from all training stressors. If the athlete wants to shamelessly do some shrugs and curls in front of the DB rack at the gym and eat pizza later, active rest provides implicit permission for these activities. If they want to play pickup basketball and later have a rousing night of dungeons and dragons complete with chips and mountain dew, these are also acceptable. Their fate is in their own hands, the only constraints being that they have enough general physical activity to maintain muscle and body composition and avoid deconditioning. The reduced training load, rigor, and unstructured nature of this phase can be effective for resolving both physical and psychological fatigue.

Expected outcomes

The specific outcomes of active rest (as distinct from those of deloading) include:

- Increases in motivation
- Increases in confidence and efficacy
- Restoration of normal sleep patterns
- Restoration of mood and affect

How to apply it

Active rest periods should be pre-planned throughout the year, but can also be used impromptu in the management of critical fatigue. Pre-planned active rest should generally be programmed after competitive cycles and grueling macrocycles of training. For athletes, these phases will occur 1-3 times throughout the year, depending on the sport and individual. For those training for general health or physique, these phases can be used after sustained periods of weight loss or weight gain, when both training and dieting fatigue can be very high.

Using an active rest phase *ad hoc* should only be done under catastrophic conditions. This would be limited to major life crises and tragedies such as a death in the family, where emotional stressors are too severe to continue training.

The length of the active rest phase primarily depends on the athlete’s training age, and the severity of accumulated fatigue. For beginners, active rest may not be necessary, as their fatigue can instead be managed via deloads and volume manipulations. Once the athlete becomes intermediately trained, active rest phases become more necessary, and will generally last about 2-3 weeks at a time. For advanced athletes, they can easily extend to 3-4 week periods, and elite athletes whose progress-yielding training is especially grueling, require 4+ weeks to fully recover and prepare for the next training cycle. The training and nutrition during these phases are unstructured and are not necessarily sport specific, making them a kind of intelligently managed free time.

Special Considerations

Active rest phases are not mandatory, and some athletes can get by without them. For those training for health and physique, the combination of dieting and training for weight loss often warrants this type of intervention. More generalized training may never require this level of fatigue management.

Additionally, active rest phases occurring more than 3 times in a given annual cycle are excessive, and likely the result of poor ongoing fatigue management. Again, the time spent in active rest serves a massive benefit in promoting recovery, but its drawback is time spent without progress. Ergo, they should be used strategically rather than as any kind of go-to.

Light Sessions

Light sessions, though the least powerful form of active recovery, may also be the most universally applicable form of active recovery to all sport and exercise. This strategy is one of our favorite pre-planned and impromptu active recovery methods. Although light sessions are of the lowest priority in active recovery, they can be very useful as both a quick fix and an advanced programming strategy tool.

What it is

A light session or "light day" is a training session in which either all or specific activities are deliberately trained at a reduced volume. The word "light" often leads to the assumption that these sessions have a lowered intensity, which they may or may not. What does characterize them is that the total work performed during the session is reflected in the perceived magnitude, or "lightness" of the session. The training consists of the exact same sport and training activities that are being performed in the current training phase, simply at a reduced total volume. Their application is not limited only to weight training. Coaches have discovered alternative activities such as pool sessions to mimic the effects of light sessions, though we speculate that, for best results, the specificity of training should be maintained, and superfluous activities should be minimized or removed entirely.

How it works

Depending on how the light session is structured it can be used to address either local or systemic fatigue. A heavy/light training split can be used to manage fatigue in specific muscles groups, whereas taking an entire light day or session can help reduce fatigue across the board. Stimulating the muscles will direct blood flow to them, enhancing nutrient uptake and waste product removal. Stimulation of the muscle also temporarily increases its insulin sensitivity and glucose transporter type 4 (GLUT4) activity, both of which aid in nutrient uptake into the cell. Because their intensity is generally maintained above minimal overload thresholds, light sessions are also thought to be sufficient in stimulating anabolic cellular regulators such as the mechanistic target of rapamycin, (mTOR), which is more sensitive to mechanotransduction and cellular energy conditions.

Provided that the athlete maintains their existing diet, taking a light day can also provide them with a temporary refueling of lost energy substrate, particularly carbohydrate. After several days of hard training, it is common for glycogen stores to be increasingly taxed. The anabolic cellular effects of a light session help shift the energy balance to favor recovery.

Those who've tried out a light session, can also attest to their psychological benefit. No matter how intrinsically driven you are, when you've been training your butt off for some time, there's an undeniable sweetness in knowing that today's training session is going to be a short one, for a change. As such, having a pre-planned or impromptu light session can help alleviate the anticipatory anxiety or mental stress associated with training.

Expected outcomes

The outcomes of taking a light session are essentially a shorter version of the list provided for deloading, where the amount of fatigue reduced is not as profound, including:

- Diminishment of perceived fatigue
- Recovery of exercise performance
- Replenishment of glycogen stores

Although not as comprehensive as a full deload, its use meritorious as it still aids recovery on measures of performance, psychology, and physiology. In some instances, a light session can have a more positive effect on stimulating recovery than planned rest, with the added benefit of continuing to refine sport and training related skills.

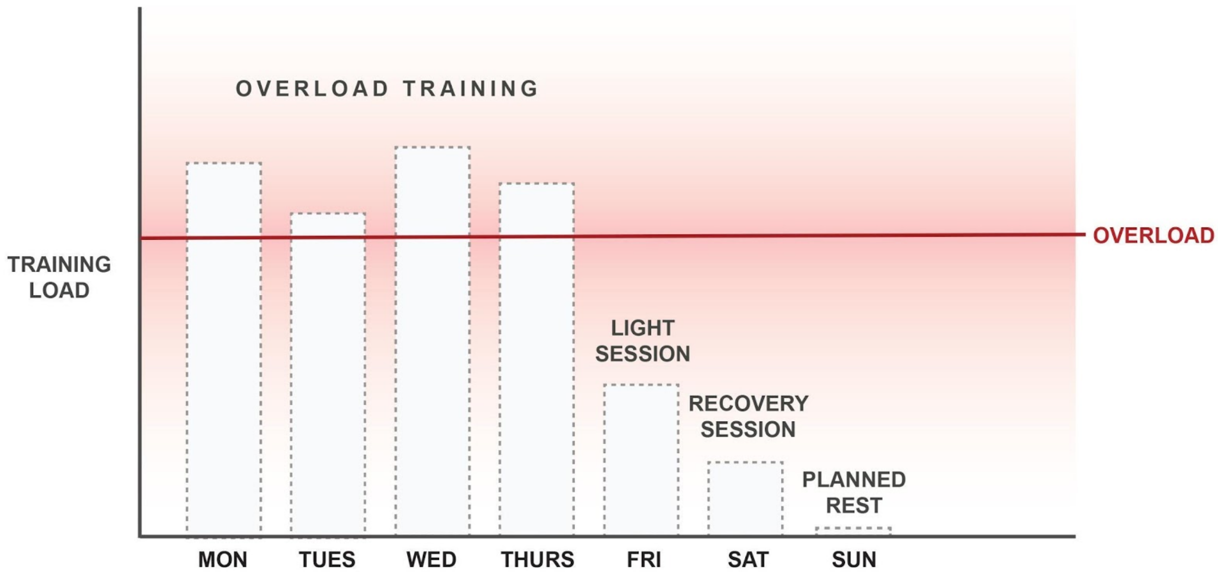
How to apply it

First let's address how to program pre-planned light sessions. The simplest application of light sessions is to lower systemic fatigue. A light session is generally about 50% of the normal overload volume for the activities being trained. For weight training, that would be roughly half of the total sets and reps; for sporting and cardio activities it would be roughly half the distances, durations, or number of efforts. The intensity of the session should generally be maintained as that of the current microcycle, and the exercise selection and activities should be the same as that of the current mesocycle. In plainer terms, a normal day cut in half would make it a light session.

If the training frequency is ≤ 4 sessions per week, a light session may not be necessary. Having ≥ 5 sessions per week, however, makes the use of light sessions increasingly valuable, and is especially so for with sport training where the combined number of sessions per week can easily exceed 10. In training for physique and health, the need for light sessions is less of a concern: taking only 1 light session per week may be adequate, as would the adoption of heavy/light training splits. For weight and certain cardiovascular training, the programming of light sessions should generally not exceed 2 light sessions per week. Sport practice, meanwhile, sessions can be altered to light sessions more liberally, depending on the number of total training sessions in the program.

Light sessions should be programmed strategically when fatigue is high, such as after lifting for 4-5 consecutive days, or as the first practice following a difficult tournament. When possible, these should lead into a planned rest period, to asymmetrically load the fatiguing and recovery portions of the training week, such as that shown in Figure 9 below.

Figure 9: Strategically programmed recovery after sequential days of overload training



A less conventional but equally valuable approach to light sessions is the use of heavy/light splits. Instead of reducing the volume of the entire session, the main focus of the session is trained at overload volumes (heavy), while another portion is deemphasized and trained at deliberately low volumes (light). The heavy portion is meant to be normal overload training, whereas the light portion is meant to stimulate recovery. As an example, if we had 2 leg sessions per week, using this idea of heavy/light splits, we could choose to emphasize quad work in one, and hamstrings/glutes in the other. Session 1 might have 10 total sets of combined quad work, but only 2-3 sets of posterior chain movements. Similarly, session 2 might have 8 total sets of posterior chain emphasis, but only 2 sets of direct quad work. In this example, the light work operates just as a light session would, only here, the recovery effects are localized, while other parts of the body continue to be overloaded. This is an advanced application of light sessions, ideal for physique athletes and for those training for health and fitness.

The light portion of the routine generally should not exceed 3-4 sets per session, and should represent a very small portion of the weekly Maximum Recoverable Volume (MRV). These light portions will start with 1-2 sets and increase slowly up to around 3. These sets should be done near the end of the session, so as not to interfere with the overloading portion of the training. The relative intensity should be only slightly lower than that of the emphasized portion, to accommodate the intra-session fatigue.

Another variation of this heavy/light split is the use of exercise selection to distinguish between the heavy and light portions. For any given muscle group, there are exercises which are inherently heavier or lighter in terms of absolute intensity: front squats vs back squats, 45 degree back raise vs stiff legged deadlifts, flat barbell bench press vs incline dumbbell bench press, etc. We can therefore choose inherently “easier” exercises to generate a light session or light emphasis within a session. Instead of doing stiff legged deadlifts twice per week, which may be too taxing to sustain, one of those session might include a lighter movement such as a “good morning” or 45 degree back extension, and the other can include the heavier stiff legged deadlift. Exercise caution with this method, as picking a lighter exercise variant reduces the absolute intensity (total weight), but not necessarily the relative intensity (percent of maximal effort), which can still be substantially physically and psychologically demanding.

There are a lot of options in the use of pre-planned light days, but they are versatile and can be used on the fly as what we like to call “damage control”. When it's clear that your athlete is having an off day, is prematurely overreaching, has had a life crisis, is physically exhausted because maybe her sport coach made her run suicides before lifting, or any other variation of being in an unacceptable training state, an unprogrammed light day can really help pull them back from the brink of utter fatigue while keeping them active. Judicious use of light days can also help prevent against more drastic interventions, like frequent deloading.

To determine whether it’s the appropriate time for a “damage control” type intervention, we take an assessment based on quantitative and qualitative observations:

- Athlete is distracted, anxious, panicking, and overly emotional
- Athlete is visibly struggling or failing to hit expected reps or weights, typically well within their capacity
- Athlete appears sickly and exhausted
- Athlete is sluggish and unable to move explosively
- Athlete’s technique has degraded to the point of being unsafe or useless

There is a fine line between athletes needing push themselves (or be encouraged by their coaches) through a low point, and needing a light day to bounce back. This highlights why having a monitoring program is crucial for good decision making for yourself and your athletes. If you have determined that a light day is warranted, take the session at hand and reduce the total volume of activities by about half. If the situation is particularly bad, the relative intensity can be reduced by 15% or more, to make it a recovery-oriented session.

Special considerations

To reiterate, there should be some evidence that an unplanned light day is warranted. More often than not, if you ask an athlete if they could use a light session, they are going to say “yes”. Performance and perceptive monitoring tools can guide you to determine if a light session is truly necessary.

Moreover, light sessions should not be used in lieu of deloading. Although light sessions provide a similar effect, they are not nearly as powerful as deloads when it comes to alleviating fatigue. If an athlete is struggling, light session can serve as the initial response, followed by planned rest. If the athlete is still struggling after 1-2 light sessions, they likely need to shift into deloading.

Although light sessions are primarily governed by reducing training volume, training intensity can be modified as well, but should generally not drop below overload intensity for the given training activity. Typical reductions in relative intensity should be around 10-15%, to modify the program to a light session. A word of caution that taking light sessions at an insufficient intensity may reduce their beneficial effects, by failing to trigger regulators of anabolism and just adding garbage volume.

Tapering

A taper is a special tool used to help maximize performance for particularly important competitions. For those training solely for physique and health purposes, this is a non-essential component of active recovery. For those who are actively competing in sport, on the other hand, this can be a useful tool to maximally alleviate fatigue, maintain existing fitness, and potentially express degrees of fitness that have been previously masked by the effects of fatigue. However, tapering is not used for all competitions, and implies some trade-offs. For these reasons, it makes up the final, seldom used and therefore least essential component of active recovery.

What it is

Tapering describes a reduction of the training stimulus in order to simultaneously lower fatigue and express preparedness. Fatigue will be alleviated through some combination of volume and intensity modifications, as described. Tapering differs from more practically applied methods in that a high intensity is maintained in order to preserve previous gains. Though there are many different taper styles and durations, all tapers have the same basic feature: the total volume of training is reduced while high intensity is preserved for the majority of the tapering period.

How it works

The taper can elicit a short-term performance enhancing effect, by reducing training volumes to maintenance values or lower. This odd phenomenon results from the interplay of three factors:

- Fitness is (thankfully!) hard to lose (via deconditioning) once it has been gained. This is even more difficult if levels of fitness have been maintained over weeks and months.
- The rate at which fatigue drops is faster than that at which deconditioning occurs, even with a total cessation in training.
- Fitness can be temporarily maintained by the intensity of exercise, even if volume is reduced to maintenance values (or potentially lower).

Although intensity plays a role in fatigue accumulation, the total volume of training is directly proportional to the total amount of fatigue generated. As such, reducing total training volume to very low values can yield a substantial drop off in fatigue. This reduction in fatigue can be so large, that the athlete may be able to express fitness characteristics, particularly the more sensitive ones, like power and speed, to an extent that they were previously unable to on a normal training day.

Expected outcomes

The benefits of tapering are vast, to say the least. Typical outcomes for tapering can include:

- Performance improvements in time trials, strength, speed, and jumping ability
- Decreased perception of effort
- Decreases in mood disturbances
- Decreased perception of fatigue
- Improved quality of sleep
- Increased vigor
- Increases in Type IIx muscle conversion
- Increases in $VO2_{max}$
- Increases in movement efficiency
- Increases in peak blood lactate / decreases in submaximal blood lactate
- Replenishment of glycogen stores
- Restoration of autonomic balance
- Restoration of endocrine (hormonal) balance
- Improvements in hematological factors
- Reduction in markers of cellular damage

Keep in mind that this is a consolidated list of the potential benefits of tapering. Tapering is a well-studied method of active recovery, and has been implemented in competition long before we fully understood its merit.

How to apply it

The total training volume should generally be reduced by about 50% from the preceding training mesocycle. If the athlete was previously training for power and speed, the amount of training during the taper can become incredibly small. Typically, we recommend a 3 phase approach to taper design:

1. A functional overreaching phase which can last three to seven days
2. A low volume high intensity phase lasting around three to seven days
3. A recovery-specific low volume, low intensity phase lasting two to three days leading into the competition

Earlier, we learned that functional overreaching—training at just above MRV for a time—can boost performance, if followed by a period of lower volume training. Deliberate functional overreaching immediately preceding the taper can drive fitness up to the highest levels of the macrocycle, before the fatigue reducing process begins. The next phase is the meat and potatoes of the taper, where volume is dropped to maintenance levels, and intensity is maintained.

Given that fatigue is alleviated more rapidly in moderate or low intensity training compared to high intensity, we reduce the intensity by approximately 50% in phase 3, which takes us into competition time. Although we have emphasized that the main benefit of tapering is to enable recovery while maintaining high-intensity training, this brief *low* intensity aspect of tapering provides athletes with an additional relief from fatigue to peak their performance.

Total rest between the end of the low volume/high intensity phase and the competition is relatively disadvantageous for two reasons. First, technique has a decay period of a day or two, tops, and every sport relies on technique. At the very least, all tapers benefit from very low intensity technical practice 1-2 days before competition, as well as very low volume, which can be at maintenance levels or potentially below at this point. Secondly, low volume and low intensity practices are recovery-oriented sessions! Because these sessions actually drop fatigue even faster and more completely than total rest in most cases, programming these sessions in the last days before a competition is usually a net benefit.

The length of the taper itself is related to the training age, size, and strength of the athlete. For beginners, there may be no distinction between benefits of several light sessions, a single deload, or a taper. On the other hand, truly elite athletes may benefit from taking more than 3 weeks to properly titrate training doses down, and express maximum preparedness. Typical taper durations range between 1-3 weeks, with 2 weeks being a widely accepted protocol for intermediates. More advanced or more heavily muscled athletes may require 3 weeks using the same 3 phase approach. For specific examples of how to taper for strength sports, check out The Scientific Principles of Strength Training.

Special Considerations

Because of the trade-off of potential gains via overload training, the use of tapers is always a strategic decision. It’s up to the coach and athlete to decide to taper and peak or to overload train, and to what extent to utilize each. While all athletes need to train as hard as they can so as to win or accomplish as much as they can, training hard all the time and never tapering means you’ll always have the fitness to win, but will be ultimately unprepared to do so. Presented with this trade-off, one must carefully consider the interval at which tapering is employed. Competing too often or tapering for too many competitions will stall your improvement. But, compete too little or only taper for the very biggest competitions, and you might be unprepared for your biggest competitions, as competing is itself a skill that needs regular practice. And, of course, sufficient unpreparedness may prevent you from qualifying at all.

Here are some sound approaches, for starters:

- Make sure beginners and intermediates spend more time training than they do competing, so that they can progress in all of their abilities.

- Compete at a moderate interval specific to your sport. Too many competitions decelerate improvement, while competing too rarely will deprive athletes of the opportunity to better acclimate to the rigors of competition.

- Taper appropriately for your most important competitions, employ modified tapers and deloads for your moderately difficult ones, and train right through the easy or unimportant ones.

If you're a football coach and your elite college team is scrimmaging Podunk State Technical College, you can likely train right through that game. But, if you're going up against a not-so-great team in your district but you need the win for rankings in the playoffs, do a mini taper to help ensure that your team is at its best. And, when you're set to play in the year-end bowl game against the defending champs, it's time to run a thorough taper from start to finish.

Active recovery methods make up a huge portion of our pre-planned recovery strategies. Appropriate programming of active recovery sessions can help manage ongoing fatigue and prevent the need for aforementioned "damage control". Once again, the purpose of active recovery is to strategically provide rest without forfeiting hard-earned gains.

So far on our journey into enhancing recovery, we have described "the big 3" methods for enhancing recovery: passive methods, nutrition, and active methods. All of these can be applied preemptively, concurrently, or as part of lifestyle modification to meet the demands of training. At this point you might be wondering: where is all the cool, funky, weird stuff? Hopefully by now it is becoming apparent that enhanced recovery is achievable by relatively ordinary means. While interventions such as ice, needles, E-Stim and trans-dimensional gravity massage exist, their effects cannot match well planned training, good rest, and scrupulous nutrition. As such, we've saved trendier methods for last for the following reasons:

- They have limited contextual use
- Their magnitude of effects is comparatively weak
- Their scientific support is not sufficiently developed
- Their effects may be confounded by other factors, particularly relaxation

Our last section on recovery modalities deals with therapeutic and supplemental strategies. Here we will investigate additional strategies that can potentially be employed after the "the big 3" have been mastered.

7 THERAPEUTIC AND SUPPLEMENTAL STRATEGIES

There are an overwhelming number of fads, misinformation, and rigmarole surrounding the topic of recovery. As fitness becomes more and more mainstream, the general population is increasingly interested in the commoditization of recovery. This creates an environment vulnerable to unscrupulous or uninformed businesses to prey upon people unable to discern legitimate options from snake oil. Most areas of sport and exercise science also suffer from this problem. Shake weights, detox cleanses, and other unstudied or debunked strategies continue to be developed—and sold!—evidencing that a lack of foundational knowledge about fitness and recovery abounds. This preponderance of misinformation and inefficacious products calls for a need to discriminate between fact and fiction. When shopping for recovery treatments, one thing to look for is peer reviewed literature confirming their efficacy. Having performed a “background check”, we’ve selected those recovery modalities that have at least some potential merit or scientific validity. The hundreds of “recovery products” that have been completely debunked will not be discussed here, out of consideration for your time.

That said, it’s worth noting that the study of recovery-adaptive strategies for sport and exercise is relatively new, and science is a fluid process, which is to say that some therapies have not yet been studied enough to draw conclusions about their usefulness. This may change over time and new methods may be developed. As new evidence emerges, strategies and therapies will continually be refined.

Temperature Based Recovery Modalities

Heat, cold, and temperature contrast have been used for decades to manage pain and injury. The effectiveness of these methods in injury treatment has led many to wonder whether temperature modalities could be used to facilitate recovery from training. While logical, recovery from injury and recovery from training can differ substantially, given that adaptation is generally a desired post-training outcome, but not an option post-injury.

Cold Application

What it is

Cold application-based recovery modalities include direct application of cold, such as icing, cold water immersion, cooling vests, and cryotherapy.

How it works

Cold methods can be applied locally by using an ice pack or a gel and with a more whole-body approach using cold water immersion or cryo chambers. The effects are largely the same regardless of how the cold is applied, but systemic application has the additional effect of reducing core temperature, and provides the ability to target harder-to-reach areas.

The effects of cold application are not entirely understood. What is known is that cold has anti-inflammatory and vasoconstricting effects. Vasoconstriction reduces flow of blood (and other biofluids) by constricting the diameter of the transport vessels in the area. The constriction reduces initial swelling and edema (accumulation of extracellular fluid), and may also blunt the inflammatory cascade generated by immune responses. The cold also reduces metabolic activity in the tissue, and can lower oxidative stress (accumulation of free radicals). With cold treatment, the muscle tissue also becomes less compliant, or more stiff, which might provide a favorable energy state for repair processes. Decreases in nerve conduction velocity as a result of cold produce an analgesic, or pain alleviating, effect. The cold also appears to help recover neuromuscular parasympathetic response, and expedite neuromuscular recovery of exercise performance.

If subsequent exercise is planned, systemic cold application can reduce elevated core temperatures. Elevated core temperature is highly associated with fatigue and decreases in performance, particularly in endurance exercise, so cooling may allow for a slight advantage. *But please be cautioned that after cooling proper warm-ups are still needed prior to subsequent exercise!*

Expected Outcomes

The effectiveness of the cold treatment largely depends on the Stimulus-Recovery-Adaptation (SRA) time course. Small disruptions in fatigue will probably see little to no benefit from cold application, while large disruptions will likely get a noticeable benefit.

Cold application effects can include:

- Decreased perception of pain
- Decreased perception of fatigue
- Increased recovery of exercise performance

One thing that should be immediately noted is that cold aids in neuromuscular recovery of performance, or the ability to make powerful and coordinated movements, rather than healing the actual structural damage to the afflicted areas. It is also important to understand that cold treatment does not actually boost performance above the athlete's baseline, so cold treatment should not be used for performance enhancement. Cold application recovers performance of sporting-type movements like jumping, sprinting, and sport tasks more so than maximal dynamic or isometric strength related tasks. Perception of pain and fatigue are generally also reduced with cold therapy. This is likely due to a combination of the treatment's analgesic and anti-inflammatory effects. Most athletes report feeling cold and stiff, but slightly less achy after cooling.

How to apply it

Research generally agrees that skin temperature must drop to approximately 10-15 degrees Celsius in order to elicit a meaningful effect on the muscle underneath it. Surface temperatures higher than this indicate insufficient penetration of cooling to the targeted tissues. Local cold application periods of about 15-20 minutes are widely accepted and can also be repeated multiple times, with breaks of about 5-20 minutes in between, or as desired.

Local application, such as placing ice packs on sore legs, and ice baths or cryo sessions have been shown to have equivalent effects in most cases. Some areas of the body, such as the shoulder girdle or hip may require immersive modalities in order to cool target tissues due to structural limitations, as these areas are further from the skin's surface, and more difficult to cool with local ice application.

If the goal is to reduce inflammation and expedite return to athletic activity, cold application should generally be performed immediately following exercise. This will help blunt the accumulation of inflammation and immune responses. Though a slight benefit may be had applying cold in the hours post exercise, the greatest benefit seems to come from doing so immediately following.

Special Considerations

Though it may seem obvious, if used improperly, application of cold can lead to skin burns, frostbite, and hypothermia. It is important to exercise caution, especially with immersive cooling, as carelessness may cause serious harm to the athlete.

Because the effects of cold have anti-inflammatory properties, they also have the potential to blunt the adaptive response. The cold allows for the enhancement of recovery at the cost of some amount of adaptation from training. This is not inherently good or bad, but it is a trade-off that coaches and athletes need to understand. Favoring recovery and employing cold therapy may be a viable tool during times when the athlete's immediate performance needs to be maintained. On the other hand, during general preparatory phases and training-focused periods, losing some of that hard-earned adaptation only to alleviate minor soreness might not be a worthwhile compromise.

An advantageous application of cold therapy during a sporting season is to use it to keep athletes performance-ready where competitions occur in rapid succession. In-season athletes may compete multiple times per week or even per day. Under these circumstances, performance is a priority over adaptation, and icing can help keep an athlete competitive. Cold therapy can also be used when the athlete is too beat up to continue their normal regimen and adaptive potential is therefore comprised. These recovery measures should be accompanied by a reassessment of the athlete's MRV or training program, as early overreach suggests that the training protocol was not designed well, or was not adjusted for recovery when unexpected fatigue arose. In the case of cold treatment for in-season or unexpectedly overreached athletes, there is a favorable trade-off being made. Since new gains are seldom made in-season, the trade-off of adaptation for recovery is desirable. When an athlete overreaches early in a mesocycle, foregoing some small amount of potential adaptation to prevent the athlete's total break-down is worthwhile. The alternative is missing out on the remaining mesocycle's potential gains, resulting from the fact that prematurely elevated fatigue would prohibit overload for its remaining microcycles. In this case icing will save the mesocycle from being completely unproductive by allowing the athlete to overload later on.

Cold therapy should be reserved for these types of trade-offs. A poor time to rely on cold therapies would be when the athlete is actively training to improve fitness, such as during preparatory phases. During these phases, athletes and coaches often turn to various cold therapies, not realizing that they are losing out on fitness gains by doing so. This is the time for "no pain no gain", "putting some hair on your chest" [insert your choice of cheesy motivational quote here] and allowing the normal discomfort and inflammation of training to run its course and make the athlete better.

One last consideration for cold is speculative, but worth mentioning. Some sports, such as Brazilian Jiu Jitsu, Golf, and Diving are more dependent upon complex exercise techniques and less so on fitness. In these sports, the ability to acquire, maintain, and refine techniques is a limiting factor to performance. This is also one of the first capacities to fade with fatigue, so using modalities such as cold therapy has the potential to allow for a greater training frequency of sports skills. This increased training allows for greater improvements in technical abilities for those athletes, possibly making it a worthwhile trade-off over fitness adaptation. More research needs to be done before this can be said with any certainty.

Heat Application

What it is

Recovery modalities using heat include hot packs and gels, warm water immersion, and acute exposure to heat in the sauna or steam room.

How it works

Just as with cold therapy, heat therapy can be applied both locally and systemically. Unlike cold, which constricts blood vessels, heat causes vasodilation to the applied areas. Vasodilation increases flow of blood and biofluids to the warmed areas. The increase in blood flow to a tissue is associated with an increase in the oxygenation, increases in nutrient availability and uptake, and removal of local waste products like CO_2, inorganic phosphates, lactate, and others. These effects also increase the metabolic activity of the tissues.

Heat also promotes muscle relaxation by downregulating muscle spindle stretch sensitivity. The relaxing effect on muscles goes hand-in-hand with psychological relaxation which is by itself is a powerful recovery tool.

Expected Outcomes

Heat application effects can include:

- Antispasmodic effects
- Reduction in Delayed Onset Muscle Soreness (DOMS)
- Analgesic effects
- Enhancements in cellular and tissue recovery
- Improved lymphatic drainage
- Psychological relaxation

Heat alone appears to aid in the physical repair of tissues, but does not improve exercise performance (unless paired with cold). This is contrary to what is seen in cold treatments, where exercise performance is recovered but damaged tissue is not.

The authors speculate that one of the major benefits of heat is its relaxation effects. This is supported through heat's effects on reducing muscle spasms, increasing the compliance of the tissues, its analgesic effects, and general soothing nature.

How to apply it

The literature suggests that a temperature of about 36 degrees Celsius at the skin's surface is needed for sufficient heat penetration. Just as with cold, there is a large inter-individual variability in heat tolerance, so coaches and athletes should take care to individualize application. Recommended application time is typically about 20-25 minutes. Repeated bouts are generally not required. Heat therapy is best applied about two hours post exercise. Unlike cold treatment, for which immediate application is preferable, applying heat should be delayed to allow for swelling and edema to settle prior to application. Note that applying heat to already swollen areas can increase the flow of blood and fluids to those areas and exacerbate swelling and inflammation.

Special Considerations

Like cold therapy, heat also bears the risk of burns and heat related illness. The head should never be directly treated with heat. The athlete should remain inactive during the treatment (not attempting to continue exercise while inside of a hot sauna!). Chronic exposure to heat is also a significant stressor and contributes to the accumulation of fatigue. Heat therapy should be applied judiciously with these potential health hazards in mind, and the maximum duration of heat application should be respected—one-hour sessions in the sauna may hurt your athlete more than help. Whether training outdoors in an extremely hot climate or relaxing in a sauna, overexposure to heat can be fatal.

Like cold, heat treatment can also potentially reduce adaptive potential after training. While heat application does not have an anti-inflammatory effect, it does increase blood and fluid flow. This hastens metabolic waste removal and lymphatic drainage, washing away molecules that aid recovery-adaptive processes. Though acting via different mechanisms, both cold and heat treatments have the capacity to limit the adaptive potential from exercise. As is the case with many of these interventions, the use of heat therapies is subject to the same cost-benefit analysis discussed for cold.

Contrast Application

What it is

As the name implies, contrast involves alternating heat and cold application, typically using saunas, water immersion, or local application techniques.

How it works

Contrast therapy takes advantage of both the anti-inflammatory, vasoconstricting effects of cold and the relaxing, vasodilating effects of heat. It has been hypothesized that alternating vasodilation and vasoconstriction creates a mechanical pumping effect within the vasculature of the muscles. Because contrast is often achieved using water immersion, it is also worth noting that there are potentially confounding effects, as the hydrostatic pressure of water immersion alone may cause the following, regardless of temperature:

- Elevated cardiac output
- Elevated muscle blood flow
- Elevated diffusion of waste products into the bloodstream
- Reduced formation of edema

This confounds some of the results of applying cold or heat therapies by way of water immersion, but improved recovery has also been verified using non-immersion modalities, so we can be sure that temperature itself also has a significant effect.

Expected Outcomes

Contrast application effects can include:

- Increased recovery of exercise performance*
- Reduction in DOMS
- Reduced edema
- Decreased perception of fatigue

- Improved lymphatic drainage
- Analgesic effects

*It should be noted that conflicting results have been reported regarding the efficacy of contrast on recovery of exercise performance. The overall consensus seems to affirm that contrast therapy aids in recovery of exercise performance based on current research; again, mixed results have been reported. It also appears that cold alone may provide a better therapeutic effect on performance.

The potential benefit of contrast therapy for recovery is the ability to address both exercise performance recovery, and physical recovery of damaged tissues. Cold or heat only address those individual issues respectively, while contrast may provide a more extensive recovery. Subjective measures such as decreased joint stiffness and a sense of "lightness" have also been reported after contrast therapy. More research is needed to unequivocally determine whether contrast therapy is overall superior to cold or heat therapies alone.

How to apply it

The heating and cooling portions will generally follow the same previously outlined temperature guidelines. For treatment using water immersion, two separate tanks of hot and cold water seem to be preferable to showers, saunas, or tubs. For local application, alternating between hot and cold packs is recommended. Heat should be at 38-44 degrees Celsius, and cold should be around 10 degrees Celsius.

Efficacious protocol recommendations vary significantly. We recommend a protocol similar to the one described by Mujika and Hausswirth (2013), though other protocols are likely fine. The athlete starts with 5-7 minutes of heat, followed by 1-2 minutes of cold. This is followed by 4 more minutes of heat and another 1-2 minutes of cold. The last pattern is repeated from there for a total of 30+ minutes, but no less than 10 minutes. It does not appear to matter if one ends with heat or cold. Contrast should be performed about 90 minutes or sooner following exercise in order to prevent the heat component from exacerbating existing swelling and edema.

Some authors have recommended a 1:1 ratio of heat:cold application, with intervals lasting around 5 minutes each, as well as starting contrast immediately following exercise. At present, there is no consensus on which protocols are the most efficacious, so coaches and athletes are advised to develop individualized protocols using these recommendations as guidelines and refining timing and dosing based on recipients' performance and feedback.

Special Considerations

We cannot stress enough the aforementioned warnings concerning heat or cold related injuries. Because contrast requires the athlete to alternate between cold and hot, this introduces the simple risks of slipping, tripping, or falling as they move from one therapy to the next. Caution should be taken to ensure a clear area free of debris and slipping hazards.

Contrast also parallels the adaptive compromise previously presented for both cold and heat therapies: contrast may actually undermine adaptive potential via multiple mechanisms. Conclusions from the research are inconsistent on this. Theoretically, trade-offs between enhancing recovery and adaptation should also be considered for contrast treatment. Research on the trade-offs for hot or cold treatment individually is clearer; contrast research may eventually share similar conclusions.

There are potential stress-related issues when using contrast. The benefits of relaxation and hydrostatic pressure when using water immersion are both potential confounders in temperature treatments, which could result in positive outcomes independent of heat or cold. In other words, the effects of being relaxed while submerged in water or of the hydrostatic pressure from the water (which can improve blood flow) might be the important variables for recovery irrespective of the water's temperature. Contrast requires a fairy frequent change in conditions, so the athlete is generally not allowed to fully relax. Switching temperature treatments from hot to cold would require the athlete to physically get up and move about, and jumping from a warm tub into nearly freezing water is inherently shocking. Although there seem to be tangible benefits to performing contrast, it may be that some of the benefits of heat or cold treatment on their own are lost by decreasing the potential for relaxation, the passive recovery modality that trumps any other in this section.

Contrast is wildly impractical for most non-professional, non-collegiate athletes. Aside from the use of hot and cold packs, which is relatively easy, one needs to have 2 separately controlled tubs for both heat and cold that the athlete can toggle between with relative ease. In the absence of homes or gyms equipped with a hot tub or sauna conveniently located adjacent to an ice bath or cryotube, athletes are faced with some very practical limitations to the contrast method.

Compression Based Recovery Modalities

Like temperature therapies, the use of compression garments has become a staple in the management of sport injuries. In fact, the acronym RICE (Rest, Ice, Compression, Elevation) is often used to describe the immediate procedures for treating injuries. Compression garments have also been suggested to aid in non-injury related recovery from exercise, and are advertised as such to the general fitness community. Although the role of compression garments in injury recovery has been widely recognized, its validity for recovery from sport and exercise is questionable.

Static Compression

What it is

Recovery modalities using static compression include the use of compression garments like sleeves, tights, shins, socks, shorts, shirts, gloves, and other garments which provide a constant (static) pressure to the applied areas.

How it works

Compression garments work by externally compressing areas of the body, which results in an increase in extravascular pressure. Compression decreases the pressure gradient between the extra and intravascular environments, leading to vasodilation and increasing blood flow. It may also reinforce the muscle pumping action that increases blood circulation, particularly in the lower extremities. These changes can be measured in both peripheral and systemic blood flow, as well as venous return.

Increases in blood flow normally result in increases in limb oxygenation, nutrient uptake, and metabolic waste removal. There is a small consensus that suggests compression may also positively act on exercise-induced muscle damage, but research is mixed: some analyses have also shown a negative effect of compression on identical or related biomarkers, such as blood lactate concentrations. The effect of compression on biomarkers currently remains unclear, but is trending towards a positive effect.

The effects of compression have also been shown to reduce post-exercise edema and swelling, and aid in recirculating excess biofluids. This effect is suspected to be a result of simply decreasing the space available for swelling, and promoting lymphatic outflow back into circulation.

Compression can also increase muscle and skin temperature. This is likely a result of both the insulating effects of the clothing, and diminished loss of heat through sweat evaporation. This could be a net positive in terms of recovery, but should be used with caution particularly in hot environments, as it also likely to be detrimental to thermoregulation during exercise.

Expected Outcomes

Compression application effects can include:

- Increased recovery of exercise performance
- Reduction in DOMS
- Reduced edema
- Decreased perception of pain
- Improved lymphatic drainage

The effects of compression treatment are somewhat unique in that they appear to aid in recovering performance in resistance-training type activities more than in jumping-and-sprinting type activities. Positive outcomes for recovery of performance can be seen for power, strength, and endurance training, with the greatest magnitude of effect being observed in higher intensity activities, and those with large eccentric components. This is slightly askew from what is normally observed in cold therapy, which favors recovery of powerful and coordinated movements and has less (if any) impact on strength recovery.

Though still not fully understood, the main effects of compression are speculated to be a result of increases in cellular regeneration and protein synthesis through the enhancement of blood flow, which helps remove waste and accelerate nutrient availability. The role of compression in clearing metabolic waste and lymph may also support the reduced perception of pain and DOMS, and hinder the accumulation of further inflammatory effects.

Some analyses have noted that the effect sizes of compressive therapies are generally less impressive than those seen in other recovery methods such as water immersion, active recovery, or carbohydrate supplementation. Because the outcomes of compression are consistently positive, however, compression therapy can still provide a significant benefit and supplement passive recovery.

How to apply it

The pressure applied will vary from garment to garment, though recommended ranges generally fall between 10-40 mmHg. There is no consensus regarding the relationship between the magnitude of pressure applied and recovery effects, nor are there currently any regionally specific recommendations. It has been suggested that a pressure of at least 15 mmHg is needed to stimulate venous return. Timing recommendations consistently cite 12-48 hours post exercise as ideal for promoting recovery. Based on what is known about the delayed effects of Stimulus Recovery Adaptation (SRA) and the proposed regeneration benefits of compression, timing recommendations may coincide with normal delayed elevations in skeletal muscle protein synthesis following exercise. This evidence is in line with the hypothesis that compression promotes cellular-level recovery. Studies have recommended anything from 2 to 48 hour windows post-exercise for compression application, though 12-48 tends to be the most common range. It might be the case that application during different time frames following exercise exert positive effects via different mechanisms.

There is no consensus on dosing in compression therapy. Until this research is fleshed out, use compression during down times as tolerated. Since static garments can generally be worn as clothing and are not overly cumbersome, they can be applied without much inconvenience.

Special Considerations

There are very few risks involved with compression outside of using excessive compressive forces, resulting in occlusion. This however becomes painfully obvious (see what we did there?!) to the user, so isn’t a risk that’s likely to do damage before it can be caught and averted. It should go without saying that compressive devices should not be applied to the head or face!

It will become intuitive to you that there is a cost-benefit analysis that must be performed when considering the use of compression. Because it removes metabolic waste and lymphatic fluids, enhanced recovery very likely comes at the cost of the adaptive potential from training. The effects of compressive therapy effects are notable but relatively small, and may best be paired with another modality such as cold therapy. In fact, applying cold and compression may be a more practical way of eliciting some of the same benefits of contrast therapy, with much less fuss and hassle. An example of combining cold and compression might involve using an ice bath immediately following a soccer match to reduce inflammation, then wearing compression stockings the following day. Both cold and compression come at some cost to adaptation. Luckily, a trained athlete won’t gain much (if any) fitness from a single soccer match, so this could be a very favorable trade-off in promoting recovery for the next match.

Dynamic Compression

What it is

Recovery modalities using dynamic compression are similar to static compressive therapies, but rather than applying a constant pressure, it is applied in periodic intervals. Dynamic compression uses special machines or garments that alter the amount of pressure across regions of the applied areas. This is typically done in a peristaltic manner, where waves of pressure move longitudinally across the limb, creating a “dough rolling” action. Examples of devices for dynamic compression include the NormaTec Recovery System and other pneumatic compression devices.

How it works

Dynamic compression for recovery is a relatively new treatment. Though still limited to a few studies, research has thus far been very positive. Given the existing data on static compression and this early research, it is likely that dynamic compression will emerge as an effective supplemental recovery modality.

If shown to be as effective as static compression, dynamic compression would likely work via the same mechanisms. It seems reasonable to assume that the “pumping” action of dynamic compression might be more effective at facilitating blood flow and reducing edema compared to static compression, but this remains to be explored.

Expected Outcomes

Given that dynamic compression overlaps with static, their shared effects will not be listed here. What has been documented specifically for dynamic compression includes:

- Improved lymphatic drainage
- Improved pressure to pain threshold
- Short term improvements in flexibility
- Reduced muscle soreness
- Reduced muscle proteolysis
- Reduced oxidative stress

One study examined the effects of dynamic compression on the pressure to pain threshold—a technique used to estimate exercise-induced muscle trauma. Results from this study indicated an increase in pressure to pain threshold following treatment with dynamic compression, suggesting a positive effect on recovery. The study did not examine the effects on recovery of exercise performance, however the finding seems to coincide with results from static compression, suggesting improvements in fluid flow and muscle regeneration.

Though outside the scope of this discussion, it’s worth noting that multiple researchers have suggested that dynamic compression may have an effect on the thixotropic properties of the muscle tissue, meaning that dynamic compression may also increase flexibility.

Reductions in muscle proteolysis and oxidative stress were also observed with dynamic compression treatment following overreaching lifting sessions in a recent study. This likely translates to attenuated secondary trauma due to inflammatory responses and faster recovery of performance, but further study in general and mechanistic research specifically are needed.

Athletes report relaxing effects from dynamic compression therapy, as well as feelings of “freshness” in the areas treated.

How to apply it

Although there is no direct data on how to use dynamic compression at the current time, some evidence-based suggestions can be made. Dynamic compression should likely be used with similar timing recommendations as static compression, between 12 and 24 hours after training. The amount of pressure generated can vary across and within devices, so athletes should choose a setting just before the point of discomfort, and avoid settings or positions that generate numbness. Doses should typically be 15-30 minutes at a time, with repetition likely fine as well. Athletes will be largely immobilized throughout the application of this therapy, so preparations should be made to find a comfortable place to rest with any gadgets, food, or necessities nearby. We recommend a bed or reclining couch, so athletes can simultaneously engage in relaxation practices.

Special Considerations

There are very few special considerations for dynamic compression, simply because the data on the subject is currently insufficient. Having personally experienced this method, we have found minimal opportunities for it to cause actual harm when applied with common sense, and find it very easy to implement. One noteworthy aspect of this treatment is that it forces the user to engage in relaxation, which may result in a valuable compounding of the effects of both compression and relaxation. Although the effects of compression may not be profound, this could potentially be used as a means to initiate relaxation practices for athletes who struggle with fatigue management. As before, there is the potential for adaptive compromise, so a cost-benefit analysis should probably be done prior to use.

Therapeutic Recovery Modalities

Social Support

Social support is an external therapeutic aspect of tending to psychological state. Whether support comes from family, friends, coaches, a therapist, or your dog; feeling loved and heard has a direct effect on your state of mind and stress levels and indirectly impacts your ability to recover from physical training.

What it is

Social support creates the perception that one is loved, valued, and has access to external assistance with life’s problems. This can mean having a trusted friend with whom to share successes and failures, a parent who will lend money in a rough patch, or a pet who offers unconditional love. It could mean access to an online community of likeminded individuals who might offer advice or encouragement, or the presence of a coach who believes in and looks out for your needs. Social support comes in many forms, but the end result is the same: a socially supported person is one who does not feel alone, insecure, or without help.

How it works

Social support is correlated with decreased morbidity and mortality in diseased states—again, no surprise that it is also correlated with improved physical recovery in a healthy state. The downstream result of social support that impacts one's recovery may amount to mere decreases in stress. There is mounting evidence that social support also impacts biological markers correlated with improved physiological health. As is often the case with psychophysical interactions, the correlations are very complicated and causality can be very difficult to parse. For our purposes, it is sufficient to say that social support is worth seeking out and reinforcing, for the sake of general well-being and physical recovery.

Expected Outcomes

Similar to a people with healthy psychological states and well-managed stress, socially supported people tend to sleep well, adapt to obstacles, and commit to training and recovery plans. These factors alone allow socially supported people to generally recover better than those without support.

How to Apply it

The application of this modality is a bit different than applying an ice pack or compression sleeves. It can involve more drastic lifestyle changes well outside of what athletes do in the gym or as part of their training. The added benefit to applying this modality for recovery is that a social support system can have positive effects extending beyond sport training as well. To employ this modality, athletes should consider the people they surround themselves with as elements that directly impact their recovery. Negative and self-involved individuals will typically fail to offer consistent support, and will also tax mental resources and increase stress. Finding a good coach, surrounding oneself with positive, genuine people, and limiting exposure to positivity and energy-sapping individuals will all add subtle enhancement to one's physical recovery, not to mention increase overall life satisfaction.

Special Considerations

Most of the research done on social support is related to its effect on mortality and morbidity in the seriously ill or elderly. It is reasonable to assume that positive health states in these cases are similar to recovery ability in a healthy state, but little explicit research on this exists. Even without this assumed connection, the minimizing effect of social support on stress is well-documented; so is the effect of stress on recovery. Though the mechanisms of action have not been completely elucidated, it's a fairly safe bet that developing a strong social support network will be a boon for your recovery and physical progress.

Compassionate Touch

Massage has traditionally been revered as one of the essentials for recovery in sport. To this day, many people balk at the idea that this may prove to be false or incomplete. However, as more recent research comes in, massage has rightly come under a greater degree of scrutiny, as data has failed to validate its effectiveness. Due to the mounting evidence, massage is best classified under the subcategory of what we like to call “compassionate touch”. Being touched in a pleasant way, or even just the possibility of having a rapport with someone (see social support) strong enough to support touching, provides some recovery improvement. Unfortunately, the effects elicited by compassionate touch are completely misunderstood in the context of stimulating recovery from sport or exercise.

What it is

Compassionate touch can include various forms of massage, sexual and non-sexual touch from loved ones, petting, and other forms of pleasant physical interaction.

How it works

This is where things get a little interesting. Previously, massage and touch were *assumed* to provide increased blood flow, increased range of motion of movement, increased metabolic clearance, and increased muscle temperature. A complete lack of evidence supporting these benefits and refutation of their existence in some cases has rendered most of these assumptions incorrect. Massage and touch do not usually apply sufficient pressure to simulate increases in flow to the skeletal muscle, or facilitate metabolite clearance, and any changes in blood flow or temperature remain completely superficial at the skin level. Massage also does not appear to have a meaningful effect on flexibility.

It turns out that the positive effects of compassionate touch are likely due to a combination of previously discussed recovery modalities. Compassionate touch decreases sympathetic and parasympathetic activity, resulting in a decrease in overall autonomic-nervous activity, and a restoration of autonomic balance. This makes a rejoinder to our most valuable modality—passive recovery. Relaxation is again the confounding factor and likely a large contributor to any positive outcome from massage and other forms of compassionate touch. The other factor at play is likely social support. The feeling that someone else cares is inherent in being touched compassionately, and probably also contributes to positive outcomes when using this modality.

Expected Outcomes

Although compassionate touch seems to provide a psychological benefit, research suggests that this modality has virtually no direct physical benefit. In other words, positive outcomes are the indirect effect of relaxation and social support, and are not caused by the physical touching action on the muscles themselves. Most assumptions about therapies like massage centered on their supposed plethora of various physical effects, which have now failed to be confirmed by research.

Compassionate touch application effects can include:

- Placebo
- Reduction in DOMS
- Reduction in low to moderate intensity pain
- Increased feelings of wellbeing
- Improved perceived recovery

Compassionate touch treatment is soothing and feels wonderful, but note that this modality only enhances perceptive measures practically speaking, not physical or performance measures. In fact, compassionate touch does not appear to have any consistent effect on recovery of exercise performance. It may even have the potential to decrease recovery of exercise performance, let alone fail to promote it.

Given its effects on autonomic activity and the feelings of being cared for by another human, compassionate touch may be an excellent strategy to promote relaxation. This is something we may do unconsciously all the time with friends and loved ones: head scratches, shoulder rubs, or back pets can quickly and easily soothe anxiety and put us in a more relaxed state. Physical and psychological relaxation are crucial components to recovery, and although compassionate touch may not provide tangible physical results for recovery, its effects on psychology cannot be denied and should be acknowledge in a holistic approach to recovery.

How to apply it

There is such a wide variety of potentially qualifying compassionate touch activities that it can only be applied in the most general sense. Massage is the best-studied compassionate touch treatment, and may be best applied within 2 hours of exercise in short sequences of about 5-12 minutes. It appears that the effects of massage are more noticeable following higher intensity activities compared to lower intensity ones. It should also be noted that massage applied after exercise does not accelerate recovery of strength, and can actually result in a temporary reduction in strength. Other forms of compassionate touch are likely best implemented to initiate or coincide with dedicated relaxation practices and can be applied more liberally, since there is very little risk associated with being kindly touched. There is no real consensus on timing and dosing, but what can be said is that time spent being physical with your loved ones is probably time well spent.

Special Considerations

The first consideration for compassionate touch therapy is that is has an a demonstrable placebo effect. This has been well documented, particularly for massage. This is also supported by findings that show increases in perceived recovery *without* corresponding increases in performance or physical recovery markers, indicating the effect is primarily perception based. Training age also factors in, as the largest effect sizes appear to be in untrained populations compared to more experienced groups.

Another important problem is that when perception of recovery is not accompanied by actual recovery, athletes come under the incorrect assumption that they are ready to overload again.

This can lead to suboptimal training, premature overreaching, and increased risk of injury, especially when perception of pain has been reduced.

Although most forms of compassionate touch are pleasant and enjoyable, there are some forms that are deliberately traumatic to muscle tissues. Extremely hard massage can often inflict structural damage to the muscle and skin and be quite painful during and after the session. While one might think that this increased pressure on the muscle might make it more effective than “only skin deep” massage, the added fatigue of tissue damage must also be taken into account. Hard, painful massage actually adds trauma and fatigue rather than taking it away, and actually decreases recovery ability despite any small benefits to blood flow etc.

Coaches and athletes should also be wary of rashes, skin sensitivity, and the potential to spread skin related illness such as ringworm when implementing compassionate touch therapies. This type of treatment is also a personal and semi-intimate interaction with another human being, which could potentially be uncomfortable for some, disabling the effects of relaxation and social support.

Studies also seem to suggest that there may be no additional positive effect from the touching aspect of compassionate touch—it may be just the compassion that enables recovery. In other words, spending time with a therapist might be equivalent to spending time with a therapist who also give you a massage. Accordingly, part of the effect of compassionate touch seems to be limited by the rapport between therapist and recipient. It does appear that trusting and knowing someone well enough to engage in compassionate touch with them is a confounding factor, suggesting that social support is one of the effectors of positive outcome for compassionate touch therapy.

Electrical Stimulation Recovery Modalities

E-Stim has been a widely accepted tool for rehabilitation and pain management for decades. Virtually every athletic training room and physical therapy clinic has an e-stim system. Considering its profound effect on healing *injured or deconditioned* muscle, many have speculated that it should also play a role in non-injury related recovery from sport and exercise.

A wise man once told us: “that doesn’t do what you think it does”. In this particular case, that thing did do what we thought it did, but there is an implicit recommendation in the statement: it is important to validate assumptions before using any treatment. In the case of E-stim and its typical usage, that wisdom amusingly rings true—the thing does not do what most people think it does.

What it is

E-stim uses the electrical stimulation of muscle fibers, using superficially applied electrodes to the muscles. Examples of E-Stim are TENS, MENS, HVPC units, and other similar devices.

How it works

The electrical stimulation of the muscle is thought to produce two major effects:

- Increases in local blood flow due to muscle contraction
- Inhibition of nociceptor signal transmission to the spinal cord

Voluntary contraction is subject to Henneman's size principle, which states that different fibers and proportions of fibers are recruited for different tasks and output needs during contraction. By contrast, electrical stimulation appears to activate muscle fibers less discriminately. Normally, when the muscle fibers are activated through voluntary action, blood flow is preferentially distributed to those areas. Under high energy demand conditions, this effect can be magnified by a process called reactive hyperemia, which increases vasodilation from hypoxia and the presence of metabolic byproducts. One of the proposed mechanisms of action for E-Stim treatment is that it can stimulate larger muscle fibers (and is not limited by Henneman's size principle) and generate more metabolites, leading to further increases in vasodilation.

It's also worth noting that E-Stim simply blocks the perception of pain, and does not necessarily treat the underlying causes. Caution is always suggested during exercise following analgesic treatments, as they result in false negative errors in perception of pain and injury.

Expected Outcomes

Effects of E-Stim therapy can include:

- Analgesic effects
- Increases in local blood flow
- Placebo

E-Stim can have a positive acute effect on the perception of pain, but very inconsistent and seemingly ineffective results in the management of DOMS. E-Stim also appears to increase blood flow to the muscle in a similar way to voluntary muscle contraction, suggesting that the increase in flow is simply due to contraction and not unique to E-Stim treatment. Some also claim that E-Stim provides an equivalent effect to that of active recovery. This would be a significant benefit, but is unproven. One of the major benefits of active recovery is the continued practice and refinement of sport skills, which an electronic device is unable provide of its own accord (that is to say, unless it is a device designed to coach you on active recovery). Drawing a comparison between the two is largely unfounded.

Reliable recovery of exercise performance has not been shown with E-stim treatment, which could be due to methodological flaws of the studies looking into E-stim. It's safe to say at the current time that E-Stim does not appear to have any meaningful effects on potentially shortening training SRA curves.

How to apply it

There is a massive variety of application methods to E-Stim, all varying in the frequencies, impulse duration, time of application, time from initial exercise, and electrode placement. We recommend seeking out exercise physiologists, athletic trainers, and physical therapists with expertise in this therapy before applying it. Strict adherence to the manufacturer's instructions is advised.

Special Considerations

This particular treatment modality is in a grey area: it does not seem to aid in recovery from sport and exercise, but does seem to have significant clinical benefits, and can be effective in treating pain. Pain is generally there to let us know that something is not quite right and can result from injury or inflammatory effects induced by hard training; pain signals to us that the hurting area needs to be at least temporarily rested and allowed to heal. Masking pain presents a problem in possibly allowing athletes to begin training before sufficient recovery has taken place, or by obscuring the fact that the athlete is exceeding his or her MRV.

While E-stim seems to be a great tool for dealing with pain, your inner skeptical sport scientist should be asking why the athlete is in pain to begin with. It is important to discern if your athlete is experiencing the pain that comes with training or pain from a physical injury.

We suspect that E-stim is a passing fad for recovery from training. We will enjoy a big slice of humble pie if that turns out to be incorrect down the road, but at present it appears to be just another fun toy that cannot replace our basic recovery strategies. Even if we assume that active recovery and E-Stim provide comparable effects, active recovery also has the benefit of continuing sport skill and tactical practice and refinement, and can activate the trained musculature with a higher degree of specificity. Thus, we would still preferentially prescribe active recovery methods.

(Dis)Honorable Mentions

So far, all of the methods we have discussed have at least some merit or potential to promote recovery. The following modalities are generally either poor strategies, ones that have no supporting data, or no indication that supporting data will ever surface. That said, let's keep in mind that some of these may be useful in recovery from injury or in other contexts outside of recovery from training.

Foam Rolling: This method has no meaningful effects on recovery, but can reduce DOMS and temporarily boost flexibility and mobility characteristics.

Cardio: This one is often confused with active recovery. *Light* cardio such as walking can be used as active recovery, but most cardio *is* overload training. Anything beyond light cardio adds fatigue instead of reducing it. Cardio does not aid in recovery in any meaningful way (outside of chronic adaptations).

Stretching: There is no apparent short or long-term benefit of stretching as a recovery modality. It may reduce DOMS, but does not demonstrate any consistent pattern of recovery enhancement.

NSAIDS: Drugs like ibuprofen have been consistently shown to blunt the adaptive response and can mask underlying injury and inflammation. This does not mean that these drugs need to be avoided at all times, but should be reserved for when an athlete is particularly uncomfortable, instead of serving as a go to every time she feels sore.

Sustained Heat Exposure: Short doses of heat or contrast may be beneficial, however sitting in a hot environment such as a sauna or steam room for more than about 30 minutes will start to accumulate effects of heat stress and dehydration without any benefit.

Recovery Drinks: If it does not have a significant dose of carbs or protein, it probably doesn't do anything meaningful.

Amino Acid Supplements: Taking BCAA's (branched chain amino acids), glutamine, leucine or the like does not appear to have any additional benefit when daily recommended amounts of complete protein are already being consumed. These are expensive and have no advantage over whey protein or other complete protein sources. Not to mention that these, if you don't mind our saying, often taste "gross".

Cupping: This treatment appears to have no meaningful effect on promoting recovery outside of placebo. Cupping also inflicts significant trauma on to the subject, adding fatigue rather than reducing it. Any potential benefit could also be confounded by relaxation or compassionate touch therapy.

Yoga: Yoga is a fine practice for other purposes, but does not appear to significantly aid in recovery from training. Any effects on recovery are likely confounded by relaxation or active recovery.

Breathing Techniques: Any effects using these techniques are likely just the result of relaxation.

Sensory Deprivation: This might offer some positive effects, but probably all are due to relaxation!

Swimming / Pool Training: Technically this is just another form of active recovery, with less specificity (for non-swimming sports). Being submerged may also add the benefit of hydrostatic pressure.

Acupuncture and Dry Needling: Both of these treatments can reduce localized pain, but it is unclear whether they produce any other meaningful effects, and are again likely to be confounded by placebo, relaxation, and compassionate touch therapy.

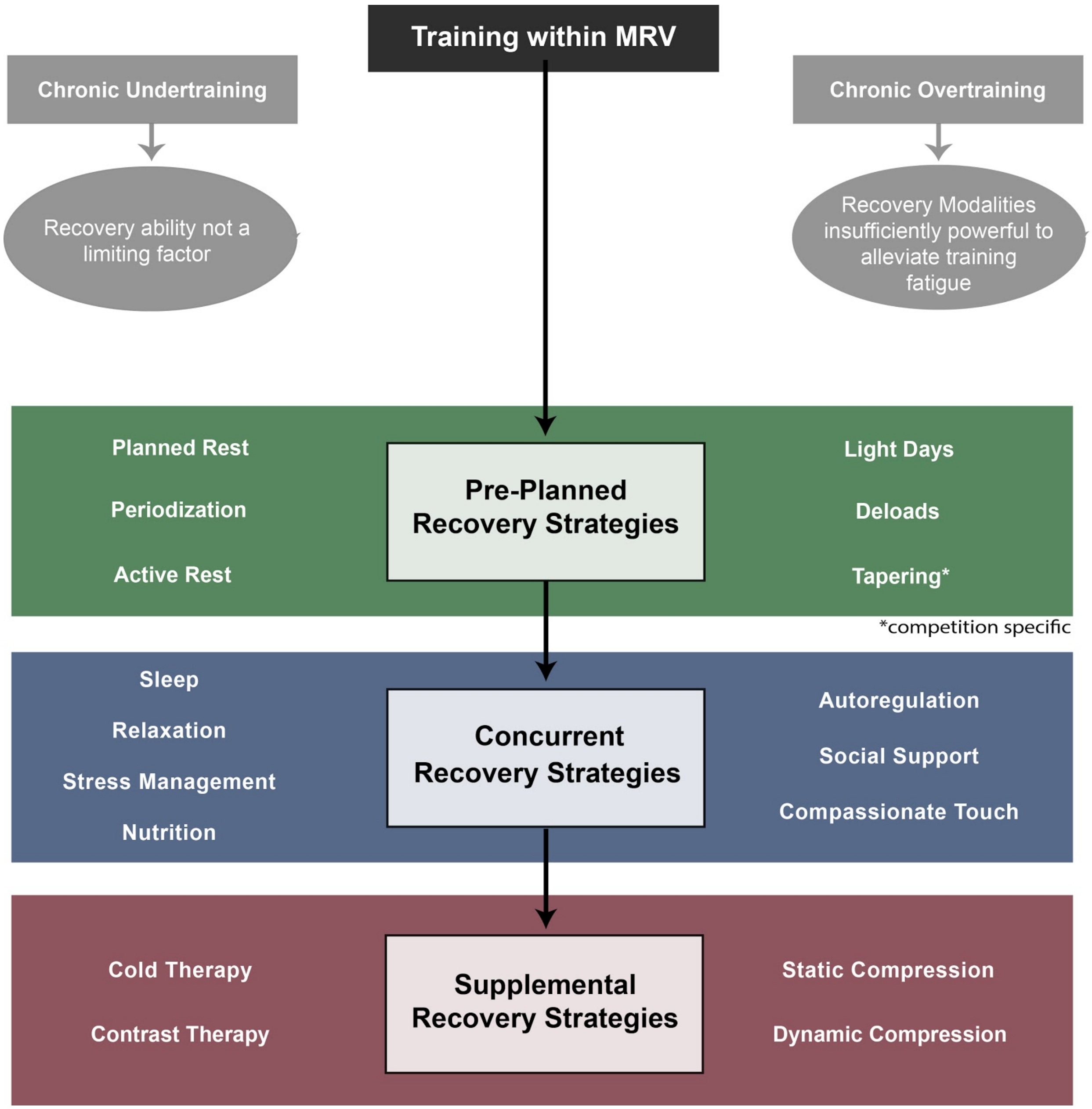
There is a quote that says *"There is no such thing as overtraining: it's all in your head."* While the "mind over matter" philosophy is common in the athletic community as a mantra for self-motivation, this is simply untrue. There are clear upper bounds to the amount of accumulated stressors one can tolerate before performance will stagnate and even regress. Following this too closely will end in injury. While some may follow the "if you're going to be dumb, you gotta be tough” approach, our philosophy guides you to aspire to be tough enough to overload train, and smart enough to properly recover from it, so that you can repeat and improve.

8 ROADMAP TO RECOVERY

Now that we have established our recovery hierarchy and discussed how each of the various methods can be used, it's time to start putting everything together. As you might have noticed, the various strategies have differing means of implementation. Some can be preemptively organized into the structure of a training plan, and others require ongoing feedback and real-time modifications throughout the training process. In order to address the time scale differences in the various recovery modalities, we have broken our approach down into the following:

1. Pre-planned strategies built into a training plan itself
2. Concurrent strategies adjusted during the training process as needed
3. Supplemental strategies which are introduced, sometimes with a trade-off, only as last resorts.

Figure 10: Time scale differences in recovery modalities



Pre-Planned Strategies

If there were only one factor in this discussion that you could address, what do you think it would be? Sleep? Good guess, but not this time. We're guilty of always assuming this goes without saying, but, frankly, it cannot be overstated: *the athlete must be training within their Maximum Recoverable Volume* **(***MRV) for any discussion of recovery or progress to be relevant.* If an athlete is consistently exceeding his MRV, there is no amount of sleep, deloading, carbs, or therapy that will allow him to recover, and therefor progress. If, on the other hand, an athlete is chronically undertraining—training below Minimum Effective Volume (MEV)—recovery strategies are not the limiting factor, and cannot promote progress without sufficient training stimulus to recovery from. Coaches and athletes must establish the appropriate volume landmarks within their training in order to fully benefit from adopting specific recovery strategies. Without this step, the entire recovery discussion is moot. For our purposes, then, all subsequent recommendations assume that the athlete is training within his or her MRV.

Our pre-planned strategies are those that can be built into a program or annual plan and accounted for ahead of time. These strategies generally stand alone, and don't require autoregulatory or impromptu alteration. When preparing a training plan, these are the recovery considerations you must build into that program before you even begin training. Pre-planned strategies include:

- **Training Within the MRV***
- Planned Rest
- Light Sessions
- Deloading
- Active Rest
- Volume Manipulations and Periodization
- Tapering (as needed basis only)

***Training within the MRV being a prerequisite for any progress**

You might notice that a majority of the pre-planned strategies come from our active recovery pyramid. Along with planning to get consistent sleep and good rest, the most important preemptive measure you can take against fatigue is employing active recovery strategies. Organizing periods of training during your mesocycle that are light enough to alleviate fatigue, but do not halt or reverse your progress is critical. In fact, active recovery methods in many sport settings can actually allow you to make gains in areas such as technical ability, while enabling recovery in other areas. In addition, in some situations, doing a small amount of training can actually drop fatigue faster than taking time off completely. As you write your mesocycle or annual training plan, a blend of passive and active recovery strategies is ideal.

Once you have established your MRV, the above strategies are the first you should consider when designing a program or annual plan. Let's go through each of these preemptive methods for designing a program that will allow for recovery, and discuss how to incorporate them into your plan as you design it.

Planned Rest

A very good starting point for program design is to install at least one off day per training microcycle, or roughly one per week. This is greatly psychologically beneficial, and seems to work well with most people's schedules. Because it's only a day, it's really hard to make the argument that it's too long to spend away from training, as almost no adaptive system loses gains over the course of 24 hours. Some might be tempted to make the argument that weekly training volume could be higher by training every day. The folly in this is that weekly volume can be elevated just as easily by increasing per-session volume of all weekly sessions. Since training above MRV is not an option anyway, adding a single session's worth of volume distributed across the other 5-6 training days will be a very small, barely noticeable addition to each session. So, don't take after those folks who insist they "need" to train every day and are a part of "Team No Days Off" (or whatever fad expression is being used for this practice nowadays).

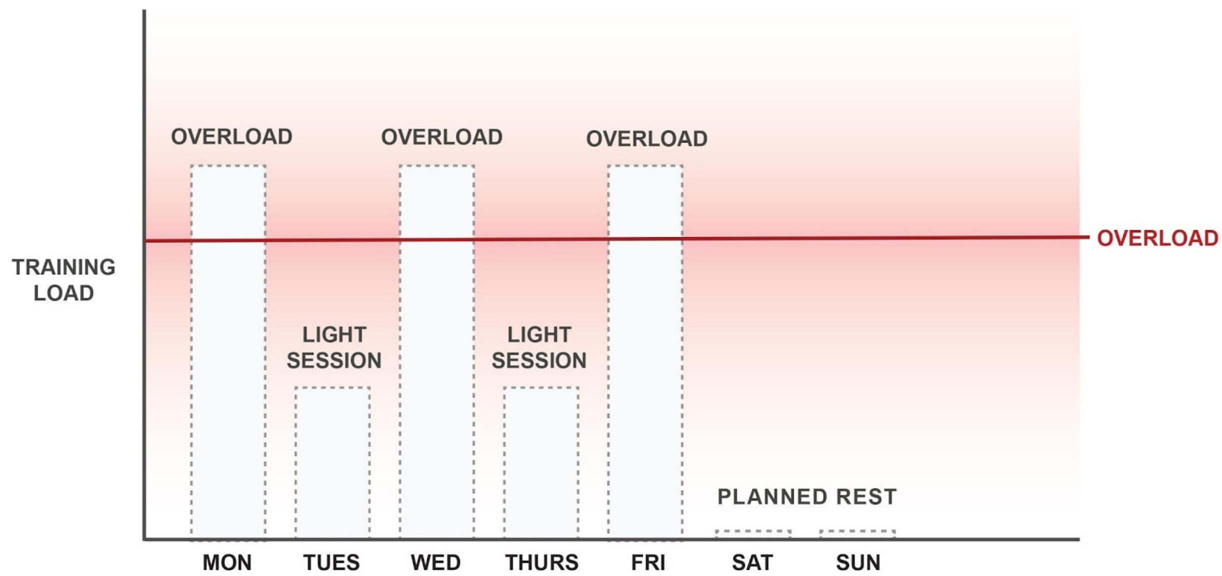
The SRA (stimulus-recovery-adaptation) Principle of training states that recovery time is what actually promotes the most adaptation, which means off days are when the gains from hard training are actually made. You can be confident that "Team No Days Off" is missing out on a very valuable recovery opportunity that has no downside, and actually limiting their potential progress by so doing. Perhaps we can rename these die hards "Team More Pain Less Gain", to call it what it is. While one day is nearly mandatory, up to two rest days per week can be taken in many sport training programs. When this is the case, our best recommendation is to take them consecutively, because the psychological recovery effects in particular seem superior for consecutive off days. After two days off in a row, many athletes are mentally and physically ready to destroy all training that comes their way, which is exactly how they need to feel going into the next overloading microcycle of training.

Light Sessions

Light sessions are another valuable tool in your training plan design. The defining aspect of a recovery session is a reduction in volume, usually by around 50% from a typical overloading session of the same training. Intensity can often be left at overload or as much as 90% of it. Because volume is the most critical factor for summing fatigue, fatigue still drops, while maintaining intensity allows adaptations to be conserved.

When planned, light sessions can allow an athlete to conserve their adaptations while dropping fatigue, and can thus be used to set up big overloads once or twice in every microcycle. In essence, one can plan to have five training days per week, with three of them being overloading. The smart way to organize this is to place the non-overloading or light sessions between the three overloading sessions. This way, every overloading session is followed by a light session to reduce fatigue, allow for adaptation, and conserve existing adaptations. Ideally, after the fifth day of training, two off days are taken and the cycle is repeated. This fairly ideal training plan can be seen in Figure 11 below.

Figure 11: Alternating overload and light training sessions to optimize recovery



A more advanced use of the above training pattern is to apply it to different aspects of training in an alternating manner. For example, bodybuilders wishing to train their shoulders and arms four times per week can take two of those days (days one and three, for best results) and dedicate them to overload for shoulders. At the end of each shoulder overload session, they can train biceps in a light session. Then, on days two and four, they can overload biceps while training shoulders in light sessions. The winning result is that both muscles get the overload and the recovery they need, accelerating progress. Overloading both muscles within the same session might make training longer, also making it harder to achieve overload for the second muscle trained due to elevated fatigue. This strategy can also be applied to different training types when more than one aspect of sport training is being overloaded within a mesocycle.

Deloading

Let's drive the MRV caveat home once more: athletes who don't believe they need to deload, they are likely training far below their MRV, and making little gains. In this case, it's not recovery but a reevaluation of overload training that is the limiting factor to progress. Training far and above MRV presents the opposite problem—deload will be needed as often as every other week, which cuts the productive training year in half! Based on our analysis of the literature, high level sport practice, and our own coaching experience, we recommend deloads to be scheduled once every three to six weeks, with particular sport demands, individual differences, and developmental states accounting for the variation.

Active Rest Phases

As a reminder, active rest phases are not to be confused with active recovery modalities themselves. Although classified within active recovery, active rest differs from the other methods in the pyramid. Most active recovery refers to structured, lighter versions or volume manipulations of the *same training* the athlete is otherwise doing. Active rest phases, on the other hand, involve taking periods of one to four weeks for non-structured training, which usually differs from what the athlete's typical training regimen. The typically recommended frequency for active rest is once per macrocycle, and it should almost always follow the conclusion of a big competition, or the end of the training season. Since minor adaptive decay is typical after an active rest phase, it should never be done right before important competitions. In some cases, two active rest phases might fit into a single macrocycle, or one year of training. Two weeks might be taken after a less demanding spring season, while a full three weeks might be needed after a more demanding fall season concludes, for example.

Generally active rest will last between one and four weeks. The length of the phase should be determined based on the average impact of the training style and the current physical and mental state of the athlete. In sports with very low impact (such as bodybuilding) or very low fatigue in general (table tennis), long layoffs from overloading training are seldom needed. In most cases, one to two weeks of active rest per year will be more than sufficient. For training that takes a much greater mental and physical toll, two to three weeks every year may be in order, with another week thrown in around the half-year mark. Soccer, basketball, and many other team sports also demand these longer active rest phases. The most active rest is needed by athletes in very high impact sports, or those who have committed incredibly high levels of psychological input into their last macrocycles. MMA fighters, gymnasts, rugby and American football players, and especially those athletes who have sustained minor physical injuries, like bruising, often require three to four weeks of active rest per year. In addition, athletes with exceptional psychological fatigue can be given longer phases. After winning at the Olympic Games or a World Championship, athletes can take three to four weeks of active rest to recharge.

Mesocycle and Annual Volume Manipulations

Keeping the training volume high all year round can lead to staleness and burnout, while keeping the volume low generally yields little progress. When training for physique and health, a lower volume phase such as a strength phase, resensitization phase, or minicut should be implemented every two to three mesocycles. High volume hypertrophy mesocycles should not be consecutively repeated for more than three mesocycles in a row, unless the athlete is a beginner and who may ride out prolonged "beginner gains". For athletes who are actively competing, the training emphasis should shift every one to three mesocycles, with three mesocycles being generally reserved only for those doing major body compositional changes, or those with a very long sport season, like hockey or basketball. For otherwise normal sport training, high to low volume emphasis should be shifted every one to two mesocycles, in order to manage fatigue and potentiate long term gains.

Tapering

Tapering is a trade-off between expressing and gaining fitness, and so should be used cautiously and strategically. For physique and health, tapering periods are unnecessary, and never planned. For competitive athletes, tapering should be performed only for the utmost important competitions which can affect rank, standing, or allow the athlete to qualify for more important competitions later on. Tapering for friendly competitions, weekend warrior excursions, or gym meets is a waste of potential progress.

We can now put all of these ideas together and start organizing weekly, monthly, and annual recovery strategies within our training plan. Table 3 below summarizes the use of our pre-planned recovery strategies.

Table 3: Recommended frequency of use and application of pre-planned strategies

PRE-PLANNED RECOVERY STRATEGIES

Recovery Method	Frequency of Use	Application
Training within MRV	Always	Establishing maintenance volume (MV), minimum effective volume (MEV), and maximum recoverable volume (MRV)
Planned Rest	At least 1x per microcycle	No structured training
Planned Light Sessions	1-2x per microcycle	50% reduction in volume, 0-15% reduction in relative intensity / Volume and intensity reduced for recovery-specific sessions
Deloading	Every 3-6 weeks / 1x per mesocycle	Placed after overreaching periods / Volume reduced to MV, Intensity maintained or reduced slightly
Mesocycle and Annual Volume Manipulations	Athletes shift training emphasis every 1-3 mesocycles / For physique and health training, shift every 2-3 mesocycles	Shifting training emphasis / Use resensitization periods
Tapering	Needs basis only	Only used for important competitions

Concurrent Strategies

This category includes manipulations that are implemented on an ongoing basis throughout training. These may be changed or modified based on outside circumstances, data collected from the monitoring program, or autoregulation. Concurrent strategies are those you will plan on implementing before you begin, but adjust on an as needed basis as you train. Concurrent strategies include:

- Sleep
- Relaxation
- Stress Management
- Nutrition
- Therapeutic Strategies
- Autoregulated Active Recovery

The above strategies are managed on an ongoing basis. Unlike our pre-planned strategies which focused heavily on active recovery methods, the bulk of our concurrent strategies come from passive recovery and nutrition. Along with therapeutic methods and autoregulated active recovery, these strategies primarily entail lifestyle modifications. Since training is not the only thing we can modify to facilitate recovery, these allow us to modify factors outside of the gym or practice field to yield the greatest possible training and adaptive potential.

Sleep

Establishing a consistent sleep schedule and wind down routine is crucial. Most recreational athletes can shoot for a consistent six to eight hours of sleep per night, while more competitive athletes should probably aim for eight to ten hours. If those quantities cannot be achieved consistently on a nightly basis, athletes should at minimum try to get an average of 8 hours per over the course of each week. Remember that sleep is one of the most critical and powerful of the recovery modalities, so it behooves one to make it an extremely high priority. So, when we say “if those hours cannot be achieved” we mean if a job schedule or other unamenable life events that prevent recommended nightly minimums from being possible. Anything that’s within the athlete’s control to change should be eliminated, if optimal athletic progress is truly a priority. The importance of consistent sleep in getting bigger, better, faster, stronger, and more technical cannot be overstated.

Napping can also be used supplementally throughout the day to help reduce fatigue levels. Naps should generally last 20-30 minutes at a time, and not be used in lieu of consistent nightly sleep. Sleep must be the priority, and napping supplemental. If sleep does not occur within about 15-20 minutes of lying down, the athlete should get up and find a low arousal activity, then try lying down to sleep again a bit later.

Relaxation

For the competitive athlete, all non-training time should be time spent relaxing. For the more recreational or non-professional athlete, relaxation time should be allocated as much as possible between training, work, family, and other commitments. For those working a typical nine to five job, relaxation time should be programmed after all of the major daily commitments have concluded. If time is extremely limited, finding 45-60 minutes per day for relaxation activities can still be highly beneficial.

Relaxation activities can be as basic sitting on the couch to watch a show, or they can be actual recreational activities the athlete finds relaxing, such as a leisurely stroll. Creative strategies can be used to pair relaxation activities with nutrition and social support (such as dinner out with friends) to help maximize adherence and combined recovery effects. Regardless of how it's achieved, physical and psychological relaxation should be a daily goal whenever possible.

Stress Management

Athletes must also practice keeping emotional responses in check throughout the day. Uncontrollable external stressors will inevitably arise, but what we can control are our reactions to them. Steps should be taken to reduce unnecessary anxiety and arousal in response to potentially stressful events, as fussing and fretting over things that cannot be changed will only hurt our athletic progress. Emotional and psychological arousal can be an effective performance enhancing tool when used strategically, enabling an athlete to “psych himself up” for a competition, for instance. When these become chronic states, however, they can lead to desensitized stress responses and even autonomic and endocrine imbalance. Stress management requires constant awareness, and should be a serious consideration for all athletes.

Nutrition

Nutrition is not a static process wherein an athlete eats the same foods in the same quantities for years on end. The demands of training can vary day to day, week to week and month to month, so one’s nutritional demands will likewise vary over time. Factoring in body compositional changes, gameday specific protocols, and individual needs, the same athlete’s nutrition program may be look drastically different at various times throughout their annual plan. Thus continued monitoring, strategic planning, and adjustments are critical to providing the energy needed to perform, and the cellular conditions needed to recover and adapt.

Calories provide the raw materials needed to maintain energy balance and tissue repair. Coaches and athletes should monitor total calories and athlete body weight, to ensure enough food is being consumed to meet performance demands and maintain structural integrity. Within those calories, protein provides the building blocks needed to grow and repair muscle tissue, and carbohydrates provide the primary energy substrate used for exercise, also enhancing cellular conditions for anabolism. Protein intake should be scaled to the athlete's body size and lean body mass, and carbohydrates scaled to the athlete's total daily workload. Fats should be used to fill in the remaining caloric needs. Athletes should also take steps to ensure the timing of meals is best suited to their training schedule, and consistently maintain a euhydrated state.

Therapeutic Strategies

Although the direct effects of social support and compassionate touch are likely very small, these strategies also facilitate relaxation and a few other recovery modalities, multiplying their impact on recovery. This is perhaps most true for social support. Athletes can seek social support from family, friend groups, teammates, coaches, and online communities. The feeling that one has others to rely on alleviates stress, which has a substantial impact on recovery. In addition, having a social group provides more opportunities for multi-modality recovery, such as dinner out with family, which promotes four distinct recovery modalities, being relaxation, stress reduction, nutrition, social support! Feeling supported and valued irrespective of sport performance also removes the sometimes consuming desire for athletes to "prove themselves", enabling them to give themselves license to take light days and otherwise ramping down training as needed, and therefore better recover. Thus while its direct effect may not be significant, the overall impact of having a supportive social network can play a huge role in an athlete's recovery.

Compassionate touch is also confounded by inherent relaxation. In most cases getting a massage, having your significant other caress your head, or even getting your feet rubbed during a pedicure promote some level of relaxation, which we have established plays an important role in fatigue alleviation. Regardless of the source of the effect, recovery is recovery; so while compassionate touch should not be an athlete's only or main means of recovering, it is certainly worthwhile, and comes with little risk to athletes or their progress.

Autoregulated Active Recovery

Unlike pre-planned recovery, autoregulated is the act of monitoring fatigue levels and only doing active recovery interventions when those levels reach a certain threshold. Once the active recovery interventions are employed and fatigue falls back down to sustainable levels, normal overload training should resume.

Proper use of autoregulation requires a few elements, some of which are discussed below.

Personal honesty

When an athlete is implementing his or her own training, autoregulation involves choosing when active recovery sessions are needed. It can be quite difficult at times to differentiate actual fatigue from a low desire to train. Though fatigue can cause a low desire to train, there are many other possible explanations, so this feeling alone is not a sure sign that recovery is needed.

In order to properly pull off autoregulation, athletes have to be honest with themselves, and take care not to mistake their laziness for intervention-necessitating fatigue. Taking light days more often than needed just results in lost progress. Autoregulation is supposed to *bring down* high fatigue, not preempt its rise. Productive training is really hard work, so periodic hesitation or intimidation in anticipation of it is natural. Be that as it may, distinguishing these from true, detrimental fatigue is something every athlete should learn to do.

A final note on this for coaches: it is wise to instruct only your most honest and hardworking athletes to autoregulate their own active recovery. Many athletes, especially younger ones or those who do sport mostly for social reasons (like many high school athletes) lack the motivation and/or personal honesty to provide an assessment of their fatigue unpolluted by laziness bias.

Accurate fatigue measurement

We will assume that the guilt trip from the last recommendation worked, and you're now willing to be honest with yourself. The next important question is how to determine that what you are feeling is actually accumulated fatigue instead of just laziness. As mentioned in Chapter 1, taking several measures or fatigue indicators is the best way to accurately conclude that an athlete is in fact fatigued. Refer back to these fatigue detection methods, and make sure there are several indicators before jumping into a light recovery session. For example, along with measures of desire to train, the athlete can assess bar heaviness feel, and perhaps jump height. Only if all of these indicate fatigue, the athlete is likely in need of some fatigue reduction.

Realistic cutoffs

Whatever your training method and goals, develop logical and realistic cutoffs for fatigue indicators, so that you have a reliable and unambiguous threshold at which you decide to employ active recovery strategies. For instance, weightlifters won't hit their best lifts every session, even with no fatigue present. So an autoregulation cutoff of "missing at least two attempts with a max weight," might lead to deloading about 75% of the training year! A more realistic and logical cutoff, like "missing three consecutive lifts with 95% of training max," might be a better strategy for choosing when to deload.

Attention to recovery results

Knowing when recovery has occurred is almost as important as knowing when it's needed. It's tough to tell whether or not the athlete is recovered without going in and testing with overload training, which of course runs the risk of ramping fatigue back up substantially if the athlete is not yet recovered. So, our best advice is to track the results of your autoregulated recovery interventions over time. If you fall below 90% of peak power output in your training, take three days of light sessions, and come back to find that you can only overload for another two days before your power output plummets again, it's likely that you need longer light sessions or even "lighter" sessions. On the other hand, if you take a weekly deload every time you have a poor performance in the gym, you might be overkilling the recovery aspect, and spending too long away from overloading training, which means missing out on best results. For serious athletes, it's important to track how recovery periods affect their bodies and attempt to tailor strategies to those responses.

If the above steps are followed and autoregulated recovery management is successful, this comes with certain benefits that are not shared by pre-planned strategies, including the below.

Recovering on time

If you only utilize pre-planned recovery strategies, some serious problems can result. Let's say you are two weeks away from the next deload and already feeling very beat up from training. Your fatigue level is too high to allow you to be productive for the next two weeks of planned overload and struggling through might even put you at injury risk. This is where concurrent strategies like autoregulation can be of great assistance. That said, it's also worth noting that athletes who are in touch with their needs and responses and are experienced at running their own training have a bit less need for autoregulatory alterations during a training cycle, because their pre-planning is generally so well done.

Everyone will run into life stressors or times where other passive modalities are deficient. Even the best of plans may require some impromptu adjustment, but the better the plan, the less extreme these modifications will need to be. For athletes whose coaches run their training, the risk of a poorly organized plan tends to be a bit greater. The coach may be very knowledgeable, but it is difficult to intimately know someone else's limits and needs, especially when coaches are overseeing many athletes at once. In addition, the team coach's burden of tracking and assessing the fatigue of each athlete is the confounder that each of those athletes responds a bit differently to the same training, and has different life stressors and passive recovery habits.

In all of these situations, it is clear that, no matter how good the plan, the ability to make concurrent adjustments for recovery is extremely valuable.

Maximizing training time

Another benefit of concurrent recovery strategies is the opposite of needing early, unplanned fatigue alleviation: sometimes, if pre-planning was imprecise or you recovered particularly well, you might find yourself staring down the barrel of a deload you don't need. If its deload week but none of the fatigue detectors from Chapter 1 are present, deloading might be a waste of your time and potential progress. Given that occasional missed opportunities to continue overload training are already problematic, endemically missed opportunities due to inaccurate programming can be devastating to the athlete's potential. If your coach says you have to take a deload every four weeks, and a two week active rest phase after every meet but you can train for five weeks on end just fine and only ever need a week of active rest after your meets, you might literally be programmed to miss out on months of beneficial training every year. If you used some elements of individual autoregulation, you might not miss out on so much potential training, and therefore progress.

If autoregulation has been sounding pretty good so far, that's because it is indeed quite the effective tool, but it does have potential problems and limitations that pre-planned active recovery strategies can best solve, up next.

Failure to reduce cumulative fatigue

If you train to overload on a regular basis, the kind of fatigue that sums up first is of the acute variety. Glycogen depletion, muscle damage, and some nervous system based fatigue will accumulate over hard days and weeks of training, requiring recovery strategy application. Acute fatigue is fairly easily and quickly resolved if the correct recovery strategies are utilized. Within several days, glycogen can be fully replenished, most muscle damage healed, and many nervous system changes restored. As acute fatigue is rises, so does more cumulative fatigue. As we train, more extensive nervous system changes, autocrine and hormonal disruption, and connective tissue damage all build up over the long term. These fatigue catalysts both rise and fall slowly, which means it takes far longer to bring them down than the several days of active recovery you're employing to alleviate acute fatigue. Eventually, accumulated fatigue symptoms will rise to very high levels, and performance will slump inexplicably, even when muscle damage is low and glycogen stores are full. In the worst case, you'll still be performing well, making you capable of producing the high forces needed to get yourself seriously hurt, as unaddressed accumulated ligament, bone, or tendon damage made these tissues more injury prone. A documented example of this is the prevalence of stress fractures in runners who fail to take enough rest days away from hard running throughout the year. Many a runner with stress fractures likely has full glycogen stores, and very limited if any muscle damage, but has simply not taken enough consecutive time away from the bone-disrupting act of running to allow for proper bone repair. The lesson here then is that relying solely on autoregulation and in the absence of pre-planned phases of active recovery increases the risk of letting your fatigue build to unsustainable levels and hitting you with a serious injury, even as your body continues to tell you it isn't in need of rest.

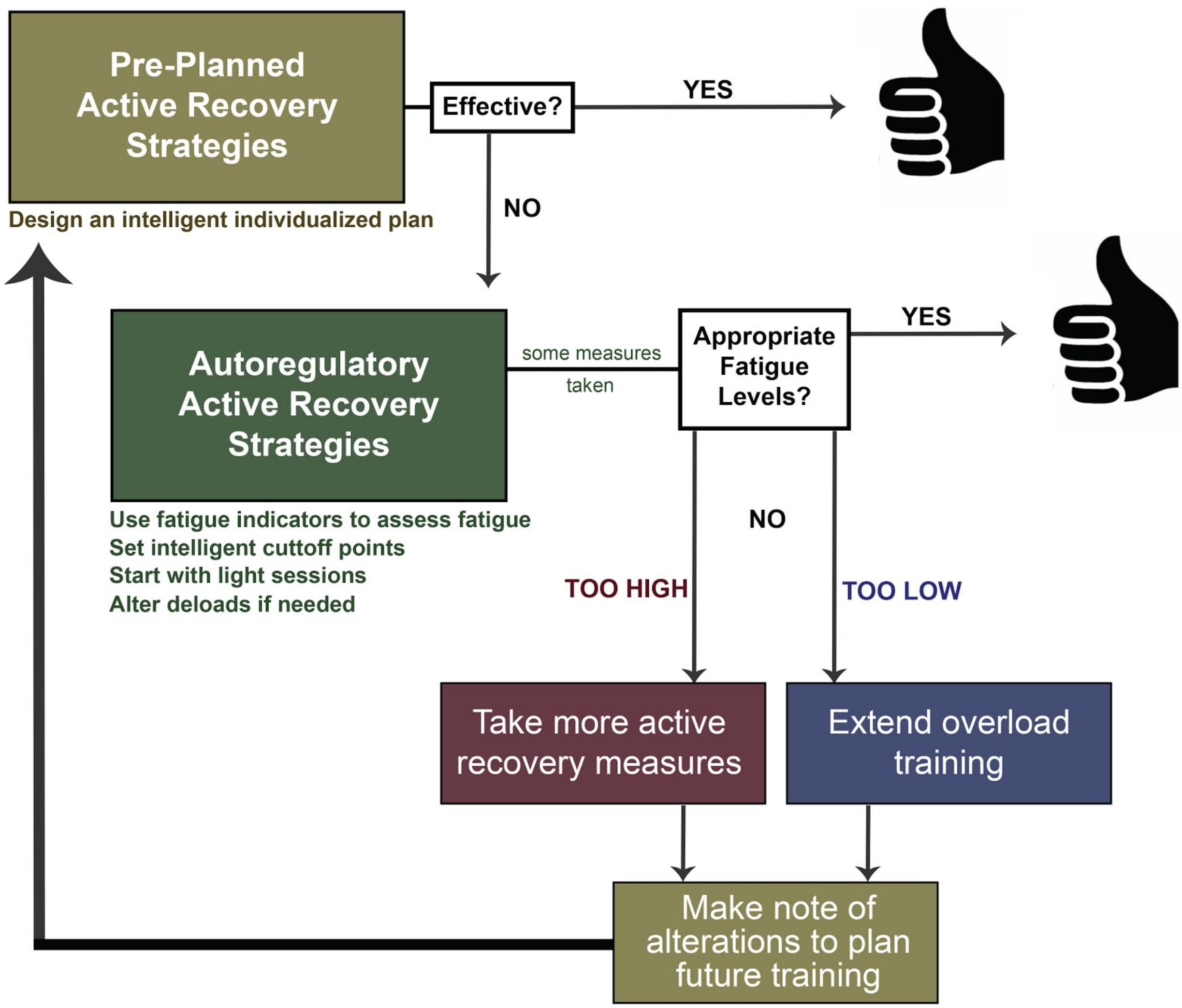
Inability to execute functional overreaching

Functional overreaching is based on the concept that going just a bit beyond your limits into overreaching can create a super-compensatory effect, which yields new levels of adaptation and performance. These effects are well documented and well-practiced all around the sport world. If you rely solely on autoregulation for recovery, however, this occasionally effective strategy is off-limits to you—any time you detect high fatigue, your response will be to intervene with active recovery and eliminate it. While this strategy is usually beneficial, it's difficult to get the benefits of functional overreaching when you consistently preempt overreaching with these reactive strategies! Pre-planned strategies allow for functional overreach and its benefits to be integrated into the training plan from the get-go.

Inability to preemptively reduce fatigue

Autoregulation is good at decreasing fatigue when it's gotten too high, but there are situations in which you are better off never having let fatigue climb to that level. The perfect example is the taper period before an important competition. To recap, tapering is the act of intentionally and preemptively lowering fatigue so that best performance can occur precisely on the date of a completion. With this in mind, if you're two days out from your powerlifting meet, do you squat heavy? Well, if you're using autoregulation strategies and no pre-planning at all, that depends on if you're feeling fatigued *at that time*. If not, you go to town on your squat training, which likely ruins you at your meet, as your chances of hitting your best numbers a couple days after a hard training session is pretty low. Because pure autoregulation has no foresight, it's highly limited in its ability to taper your training and allow you to express peak fitness effectively.

The best approach by far to properly employing active recovery strategies is to use a combination of pre-planned and autoregulated approaches. The process will look something like this:



As we can see, proper approach to active recovery is both planned and autoregulated to some degree: start with a good plan, alter it when the situation calls for it, and change it to incorporate the most effective recovery strategies as you learn what works over time. A reminder here that, although active recovery methods are incredibly powerful fatigue management tools, they are still outranked by the passive recovery strategies. Why is this? Because, while active recovery strategies are indispensable for regular fatigue reduction, they always come at the cost of lowering the overload, which means the more of them we use, the less overload we present over time, and hence the slower we progress. Meanwhile, our passive strategies and recovery-focused nutrition reduce fatigue without any cost to overload. These concurrent recovery strategies not only reduce fatigue, but also play critical roles in the processes of adaptation. By using them the most, you net out with lowered fatigue, allowing you to train with overloads more often, as well as a higher adaptive response, allowing you to benefit from those overloads even more. No amount of light days or recovery-oriented sessions will ever beat getting a full night's sleep and eating according to your needs. In a nutshell, to be on track for maximum results, rely mostly on the passive recovery strategies, and use the active ones when they are needed.

Bringing these recommendations together produces a holistic recovery approach, comprised of concurrent strategies managed on an ongoing basis, as summarized in Table 4 below.

Table 4: Recommended frequency of use and application of concurrent strategies

CONCURRENT RECOVERY STRATEGIES

Recovery Method	Frequency of Use	Application
Nightly Sleep	Always / Consistently	6-10 hours on a weekly average depending on fatigue levels
Stress management	Always / Consistently	Minimize emotional responses, engage in low stress behaviors
Nutrition	Always / Consistently	Consuming sufficient calories, protein, carbohydrate, and water to meet daily needs
Therapeutic Strategies	Always / Consistently with increases as needed	Use of social support, therapy, and time with loved ones to manage stressors
Relaxation	As much as possible / at least 45 minutes per day	Find activities that reduce psychological arousal and minimize physical work
Naps	As needed	20-30 minutes at a time
Autoregulated Active Recovery	Occasionally / As needed	Light sessions, deloads, and active rest phases when fatigue is excessive

Supplemental Strategies

This category consists of methods that may provide an additional enhancement of recovery under special circumstances, but may also imply trade-offs for that recovery. These strategies are not essential, and should only be implemented once all previously listed strategies are covered. There are quite a few supplemental strategies out there, but we have condensed the list here to the most evidence-based and useful ones available at this time. This list may certainly change as new evidence for or against some of these modalities emerges, and as new modalities are developed, but those listed here have at least some evidence to support their efficacy. Again, keep in mind the effect size of these strategies is very small, their uses more situational and often characterized by trade-offs, and they should generally only be employed after exhausting the pre-planned and concurrent strategies.

Thermal and compressive strategies are supplemental methods that enhance recovery at the cost of some of the adaptive potential from training. This effect can be seen below in figure 12.

Figure 12: Qualitative representation potential effects of supplemental recovery modalities on adaptive potential

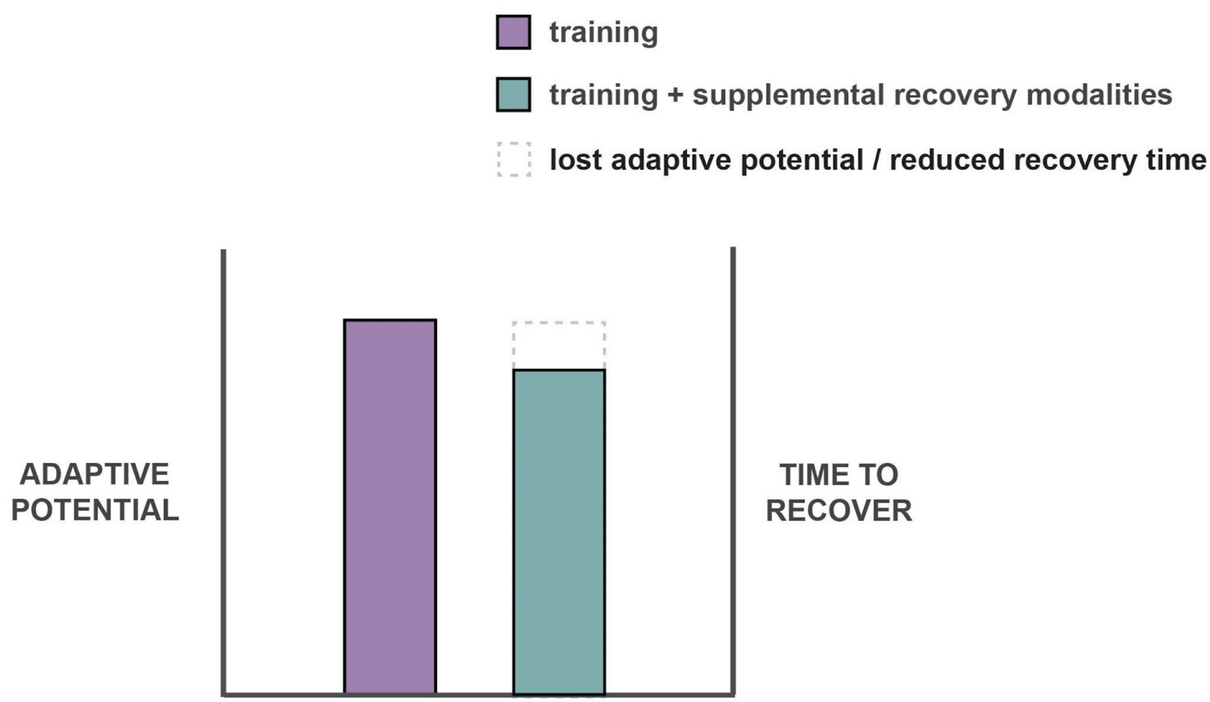


Figure 12: A comparison of training (purple) versus training and using supplemental recovery modalities (teal) on adaptive potential (left y-axis) as well as recovery time (right y-axis). While time to recover is reduced, so is adaptive potential resulting from the training (these reductions are indicated by a dashed outline).

This effect is relatively small, so for occasional use it's a fairly minor concern, however chronic overuse of thermal and compressive treatment may lead to “death by bee stings”, resulting in significant gains being squandered over the years. Although this has not been adequately studied, some have speculated that, if the recovery timescale is reduced—say, thanks to use of thermal and compressive treatments—more frequent training may occur, and thus elevate the adaptive potential, making up for those lost gains. We would counter that the total volume of training per week or per month has a greater effect on how much fitness is gained. These modalities are probably best reserved for cases that prioritize training to acquire or refine skills and techniques over maximally increasing fitness characteristics. In other words, if technique is a rate limiting factor in training, losing out on some strength gains but recovering enough to do extra technique work is a worthwhile trade-off. On the other hand, if your goal is to become as strong as you possibly can over your career, these methods are likely best avoided or used sparingly.

Here are some situations when using thermal or compressive modalities may provide a favorable trade-off:

- When muscle or joint pain is a limiting factor to training
- During an athlete's competitive season, when performance demands and competitions are frequent
- When a peak training session is coming up, but sufficient recovery from the previous session has not yet occurred
- If a new training phase is about to begin, but sufficient recovery from deloading has not yet occurred
- During tapering periods, for later in an athlete’s career
- Encountering unplanned physical stressors that may inhibit subsequent training

Thermal Strategies

Cold and contrast appear to provide a unique anti-inflammatory effect, and can also aid in the recovery of exercise performance. Heat by itself does not appear to be have a profound effect, though may aid in tissue regeneration. When paired with cold in contrast therapy, heat may be more effective. Cold and contrast appear to be particularly useful in managing joint and muscle pain from training, as well as recovering decreased exercise performance due to fatigue factors. Contrast can be difficult to implement in a reasonable manner, making cold therapy the more practical of the three. Cold can be used as more of a quick fix when the athlete is sore in specific areas of the body, whereas contrast might be used preferentially if pain and edema are present.

Compressive Strategies

The main benefits of using compressive garments revolves around their ability to improve the flow of various fluids within the compressed tissues. This is particularly useful in managing swelling and edema from training, and also appears to enhance tissue regeneration.

Compressive garments also seem to aid in pain management and recovering exercise performance, possibly through different mechanisms than cold therapy.

The use of static garments is handy, in that they can be worn as plain clothes that do not obstruct everyday activities, and also do not require any additional time or hoop jumping for "implementation" (above simply getting dressed, which most people do daily, regardless)! Dynamic compression is much more cumbersome, in that it requires somewhat bulky equipment and the athlete is immobilized during application. This treatment may be able to elicit a stronger compressive effect due to its peristaltic nature, which could potentially enhance blood flow to compressed tissues to a greater degree than static garments. Static garments may be better suited for minor swelling and pain from training or sport related contact, whereas dynamic compression may be more appropriate for significant swelling and general feelings of fatigue and soreness in the appendages.

Table 5: Recommended timing of use and application of supplemental strategies

SUPPLEMENTAL RECOVERY STRATEGIES

Recovery Method	Timing of Use	Application
Cold Therapy	Immediately post-training	15-20 minute bouts with breaks and repetitions as needed
Contrast Therapy	0-90 minutes post-training	Alternating bouts of cold and heat for a total time of 10-30 minutes
Static Compression	12-48 hours post-training	Set it and forget it Continue as desired
Dynamic Compression	12-24 hours post-training	15-30 minute bouts with breaks and repetitions as desired

It may be that the greatest benefit of these supplemental strategies is in their combined rather than isolated use. Although not much is known about this at present, we lean towards this notion because, while as individual therapies their effect sizes are relatively weak, a strategic combination may potentially yield a greater effect. A rugby player could jump in an ice bath immediately after a rough full contact practice, then, then slap on compressive garment later in the day while she relaxed, ate, and went about her day.

There are plenty of other purported supplemental recovery strategies out there, but those listed here are presently the only ones with confirmed and reliable recovery effects in our view. That being said, even these treatments are not game changers by any means, and can only offer a marginal benefit to a well-structured fatigue management program. These strategies should not be the first stop on the road to recovery, but more of an optional pit stop, to help alleviate bumps in the road.

Putting it All Together

We now have a recovery based priority system in place, as well as timescales for the appropriate use of these methods. The first step is integrating pre-planned strategies into our training plans. When done well, this covers all of the factors that can be controlled at the outset of a training program. The trickier, though often less work-intensive portion, is trying to manage factors outside of our control, as we progress through the training cycle.

In order to continue training through the normal chaos of life and make solid evidence-based decisions, an athlete-monitoring program must be in effect, to provide quantitative and qualitative support. Concurrent strategies can then be applied based on the data collected as training proceeds. More plainly put: changes should be made based on evidence that suggests the athlete is not in an acceptable training state. Real world monitoring doesn’t require supercomputers and fancy laboratory equipment—often times, all you need is a pen and a piece of paper. Looking back to Chapter 1, we already have a great list of leading, concurrent, and lagging indicators of fatigue that we can use to collect these needed data. Once pre-planned strategies have been selected, forming the outline of the training plan, the next step is to develop a personalized monitoring program, to guide the athlete in the use of concurrent strategies.

If the athlete's body weight is too low, we can adjust nutrition. If the athlete is consistently too fatigued, we can adjust sleep and relaxation. If the athlete is suffering from anxiety, mood disturbances, or burnout, we can look into therapeutic modalities and active rest. If the athlete had to save a dozen kittens from an erupting volcano prior to training, we can autoregulate our active recovery. Finally, under special conditions, we can entertain the idea of using our supplemental strategies in a strategic manner.

9 

RECOVERY TOOLBOX

The science behind recovery is undoubtedly confusing at times. Many proposed recovery-enhancing techniques may pass as common sense or logical to the untrained eye or trusting mind. The reality is that you will encounter an array of recommendations, many of which will be largely unsubstantiated or outright erroneous, leaving it up to you to discern which are effective recovery-adaptive strategies, and which are mere novelties. By reading this book, you have already taken a big step towards filling your recovery toolbox with strategies that work, and can now build on this solid foundation. In other words, you should now have some guidelines for evaluating the validity of any new methods you come across. Below is a short list of questions that can further help you narrow down your choices for recovery, and can also apply to just about any practice or product in the sport and exercise sciences:

- What does the scientific literature say on this method?
- How does it actually work in promoting recovery-adaptation?
- Is the net effect of this method adding fatigue or removing fatigue?
- Can this method be explained or confounded by an already established method?
- What are the potential benefits and risks of using this method?
- What is the potential magnitude of effect?
- Is there an appropriate timescale for use of this method?
- Do I have any personal experience or evidence to support or refute this method?

Let's take a look at how to apply all of these questions in more detail:

What does the scientific literature say on this method?

Many of you reading this book are exercise enthusiasts and athletes in some capacity, but may not have the time or desire to pour over scientific papers on the subject of various recovery modalities—provided sufficient research-based literature exists for all of them, which, as we've found is not necessarily the case! The bad news is that there is no great substitute for validating a purportedly scientific approach short of digging up and reading the scientific literature on it. The good news, however, is that if that method or topic does not yet have a comprehensive literature review and meta-analysis, that's a good clue in itself that the jury is out on its effectiveness, so it's best skipped for the time being, until more data becomes available on the causal nature of any trends or consistent pattern of findings therein. If the scientific literature for a given method exists, it goes into the “maybe” pile, making the next step to read these studies, and look for a clear positive trend in its use, which, if present, means it’s worth further investigation, should you have the time and desire to perform it.

It should also be noted that, as in many scientific disciplines, there is a general publishing bias in the sport and exercise science literature of predominantly publishing studies which show a positive result. Much of the research on methods present negative or inconclusive results does not make it to publication. Unfortunately, this denies readers access to the knowledge that something has already been tested and was found to be ineffective! Likewise, positive results are often produced with poor study design, or, worse yet, a blatant bias in selection criteria. This means that even if a study seems to indicate positive results, we still have to be vigilant against those that have dubious methods.

When confronted with conflicting evidence on a particular topic, it is usually best to filter studies by their methods, to determine the net trend or the ratio of positive:negative results, favoring studies performed within the last 10-15 years over those performed >15 years ago. Older studies can still provide a useful understanding of a topic or mechanism, but you may also intuit that studies which are too old draw false conclusions about highly complex processes, simply because the scientists performing them may have lacked the technologically advanced tools and techniques to assess them as thoroughly as we can today.

How does it actually work in promoting recovery-adaptation?

If a method has been thoroughly vetted through step 1, we should be able to find some clear evidence of *how* this method works. If you are not able to answer the question of “How does this work?” concretely, or without relying on metaphysical explanations like chi, toxins or karma dragons, then it is best to move on from the proposed method. If you can find a clear mechanism of action, such as increasing blood flow to muscles, enhancing nutrient uptake, promoting autonomic regulation, etc. that method is likely worth further investigation. This question acts as a nice filter, because, not only does it help us understand how to actually apply the method, should we so choose, but also provides a reliable gauge for “weeding out” phenomenon we simply do not understand sufficiently to conclude upon. Until we can explain how it works, it remains an indefinite maybe.

Is the net effect of this method adding fatigue or removing fatigue?

This is by far our favorite question to ask, because, although it may seem obvious at the moment, many athletes and coaches fail to examine this aspect of a new recovery method. If we invest time, effort, and money into a new method, are we ultimately removing existing stressors from the mix, or actually adding more to it? Active recovery methods highlight this idea spectacularly, in that, while active recovery generally requires that some exercise is performed, and performing exercise adds fatigue. The amount of fatigue introduced by this modality is very small, however, while its recovery effect is large enough to create a net positive effect on recovery. By contrast, something like sitting in the sauna or steam room for an hour, a widely accepted (though misinterpreted) recovery method, does not require exercise, and hence masquerades as a method that would not add fatigue. As such, it would be easy to assume that this method yields a net positive on recovery, except that prolonged heat exposure actually subjects us to heat stress and dehydration, which injure and kill every year. As a result, any benefit gained from the acute heat exposure is washed out by its large negative effects of this method, as one that in fact adds, instead of removes, fatigue.

In order for a method to pass this test, it must clearly demonstrate a net positive effect on fatigue. If the net effect is adding fatigue, such as doing more overload training, then it is not a recovery enhancement.

Can this method be explained or confounded by an already established method?

Many a sexy, "new" recovery gimmick is often a repackaged version of an existing technique, whose supposed benefits can sometimes be explained or confounded by an already established method. Common examples of this are activities that promote relaxation. We learned earlier that relaxation is a powerful autonomic regulator, achieved by lowering physical and psychological arousal. Meditation and controlled breathing are in themselves relaxation techniques. Other examples such as massage, compression, and cold application are techniques which appear to have a unique benefit, but are also confounded by the fact that they inherently require the athlete to relax. Given this, can we confidently assert that these specific treatments have a positive recovery effect, or are all of their positive effects confounded by lowering arousal? One could argue that something like massage or meditation may be catalysts for promoting relaxation, with which we would tend to agree. It's important to understand the treatment mechanistically, but also to be able to identify confounding factors.

Other examples of this can be seen with treatments such as pool sessions, "shake outs," pre-contest prep sessions, and "movement" training. All of these are little more than trendy, albeit likely "fun", light sessions. There is no magical quality to being in the pool, or to doing light gymnastic work: it is simply light physical activity, which is a great way to manage fatigue. Rest assured, you can get the same effect from taking conventional light sessions. Let's also recall that light training within the constraints of specificity allow the athlete to continue improving their sport and training related skills and tactics. So, while an easy swimming session may help bring down a boxer's fatigue, that time could be better spent doing some light sparring, which would yield both fatigue alleviation and sport-specific practice. The moral of the story is that athletes can always benefit from weighing their options, and choosing those which are tried, true and likeliest to help them excel in their particular sport, fads notwithstanding.

What are the potential benefits and risks of using this method?

Good critical thinking skills require us to outline the potential uses of any given method and the problems that come with it. We might find that a recovery method can be very useful in addressing some aspects of fatigue, but potentially detrimental for others. By assessing all major benefits and risks, we can identify potential situations where the method in question would be appropriate. Many modalities are not one-size-fits-all approaches, as some only provide a unique benefit to certain sports or activities at certain points in the athlete's career development or annual plan. We might also find that a particular method creates more total risk than benefit. Some methods may require substantially more time, money, or resources to implement, which must also be considered before trying them on for size.

Thermal and compression are great examples of this concept. Although they provide an enhancement of recovery, it comes at the expense of a small portion of adaptive potential. Ergo, their use should be limited to times when recovery is more important than gaining fitness, such as during a competitive season. If used during preparatory periods, the trade-off is unfavorable.

One common misapplication of cost-benefit analysis for strength athletes is to do cardio for enhancing intra-training session recovery, or time efficiency while lifting. The thought is that endurance training outside of lifting will help them get more quickly from one set to the next during weight training, making their lifting sessions more efficient. Is doing cardio an effective strategy to enhance intra-session lifting recovery? Actually, yes, it carries the distinct benefit of being able to speed up set to set recovery, but this benefit comes at some big costs. For strength sports, using this method means making a specificity violation, by doing training that does not directly lead to success in your sport. Moreover, this additional training reduces the MRV that can be achieved for strength training, and, at its worst, actually contributes additional fatigue. Ouch! For strength sport, then, sprinkling in cardio introduces more risk than benefit.

What is the potential magnitude of effect?

There is a flaw in thinking that, just because a method has an effect, it must be critically important, and those without effects must be discarded. In sport and exercise science, we use statistical tools to answer the question: “Is there an effect of the treatment?” Note, however, that the answer only tells us if the treatment provides a *mathematically* different effect pre-testing versus post-testing. It does not tell us how powerful that effect is—for that we use another set of tools called “effect sizes”. These can be as simple as percentage change or something more elaborate, like a Cohen’s D measurement. The effect size tells us more about the practical significance of the treatment, or how powerful it is.

The problem lies in the reality that not all treatments are uniform in statistical and practical significance, as some may not pass statistical tests but have meaningful effect sizes, and vice-versa. Sure, some use cases are very clear: the effects of sleep deprivation are both almost always statistically significant, and have large effect sizes. Others, like compression, may have statistical significance, but very weak effect sizes, indicating that something is at work, but is not terribly impactful. Some may not have any statistical differences, but meaningful effect sizes, which is often due to having a small cohort in the study or inaccurate outcome measurements. Although this may sound like scientific and mathematical jargon, we cannot only look at the statistical tests, but must also observe the magnitudes of the treatment effects. The effect size can provide us meaningful information on how powerful the treatment can be, even if the treatment did not have a statistically significant effect.

Is there an appropriate timescale of use for this method?

The effectiveness of some recovery methods may depend on when they are implemented. Some methods, such as stress management, might be used continuously, where taking an ice bath is most beneficial immediately after training. In order to understand the timescale of use, the mechanism of action should be reviewed. Once the timescale has been established, the method can be added as one of your the pre-planned, concurrent, or supplemental strategies.

Do I have any personal experience or evidence to support or refute this method?

Last and, well, least, we can fall back on anecdote and experience. One problem you will find is that the fitness industry outpaces the sport and exercise sciences, so new revelations come and go before scientists even get Institutional Review Board (IRB) approval to study last year's fads. You will inevitably encounter new, enticing products and practices and ideally you would check for direct scientific evidence of their efficacy before using them. Since that is not always an option, you can settle for trial and error, provided, of course, that the method in question can be attempted safely—if not, drop it and back away slowly!

While you may not have your own research lab and complex statistical software, that does not mean you can't collect your own data. True evidence-based practice comes from using the available scientific literature coupled with your own experience. You might find that a new method has a practical effect (which is great), but, before making it a fundamental part of your program, return to step 1 and investigate further. Anecdotal evidence is wonderful for generating interest, but poor for providing strong, scientific support for a given method. Again, primary support should always come from direct scientific evidence, and can then be bolstered with experience from users.

If a method fulfills all the above criteria, then it is probably worth a go! If, on the other hand, we are unable to cogently answer these questions for a given method, it gets filed away under "maybe", until we have a better understanding of its workings. No matter how promising or intriguing, it pays to keep in mind that any recovery method must bear the burden of proof, as your time, effort, and recovery ability are all finite resources, not to be carelessly squandered.

You wouldn't try to get strong by only lifting the pink dumbbells, right? So only use the least effective methods to recover? We know that passive recovery, nutrition, and active recovery methods are most impactful interventions in our recovery discussion, yet, because they lack the sexiness of something that is new and appears effortless, a lot of folks would prefer to ignore them, and reach for the gimmicks instead. Unfortunately for them, the best recovery strategies are often the simplest, although, as we have seen, the mechanisms by which they aid recovery are deeply complex. If your goal is to be the best athlete that you can be, your to do list should be as simple as this:

1. Train hard and push your limits from time to time
2. Rest hard and sleep every night
3. Keep your cool, be positive, and don't let your frustrations get the better of you

4. Follow your nutrition plan—no excuses!
5. Have some light training planned every week, month, and throughout the year
6. Take breaks when you need them
7. Lean on those closest to you for help and encouragement when you need it most
8. Carry a big recovery toolbox, and know how to use all the tools within it

If you can execute these 8 points, you're 95% of the way there. There may be a few additional tools you can pick up along the way, but what we have provided in this book are the core components of recovery-adaptive strategies. And, always remember that in order to manage fatigue, you must first generate it! Use these strategies to overcome fatigue's subjugating effects, and embrace the rigors of your training, so you can also reap its full rewards!

Closing Thoughts

It seems appropriate to close with these wise words, which summarize one of the central themes of this book:

“*It is important to note that Recovery-Adaptive (RA) strategies and techniques are not sufficiently powerful to overcome stupid coaching, bad planning, or lack of talent”*

Dr. William A. Sands

We sincerely hope you enjoyed this book, and make use of the concepts presented here to improve your own training, recovery, and progress. When we talk about recovery enhancement, the first thing people tend to ask is: “What should I be *adding* to help me recover?” As you might have noticed, a recurring recovery theme here is that optimal recovery is more about what you *don’t do* than what you do. It is not so much about adding new things, but, rather, doing a damn good job at the basics. It's not about circumventing challenges, but about embracing and managing them. Good recovery practices alter your life, and help you be the most productive you can be. This requires discipline, honesty, and humility. At times, it requires you to sacrifice things you enjoy, and rally for every inch of improvement you can get.

It’s our belief and experience that learning the skills required to optimize your recovery can also broadly benefit you in many aspects of your life. If you can manage training, nutrition, your ego, your time and your stress levels, you’re already doing better than most—a pretty significant bonus to simply following an intelligent training program! Not unlike designing and executing a successful training program, being a kick-ass person requires some planning, hard work, consistency, stress management, support from friends and family, perseverance, and recovery time to recharge your batteries every now and again. So, it seems to us that those who can rearrange their lives to support the rigors of training stand to become winners outside of their sport, just as much as within it.

Resources and Further Reading

Foundational Texts

Recovery for Performance in Sport

Tapering and Peaking for Optimal Performance

Periodization:Theory and Methodology of Training (5th Ed)

Principles and Practice of Resistance Training

The Scientific Principles of Strength Training

How Much Should I Train? An Introduction to Training Volume Landmarks

Foundational Reviews

Basic Recovery Aids: What's the Evidence?

Fatigue and Recovery in Rugby: A Review

Overview: Recovery and Adaptation

Team Sport Athletes' Perceptions and Use of Recovery Strategies: A Mixed-Methods Survey Study

Using Recovery Modalities Between Training Sessions in Elite Athletes. Does it Help?

Thermal Treatments

Cold-Water Immersion (Cryotherapy) for Preventing and Treating Muscle Soreness After Exercise

Cooling and Performance Recovery of Trained Athletes: A Meta-Analytical Review

Effects of Cold Water Immersion and Contrast Water Therapy for Recovery from Team Sport: A Systematic Review and Meta-Analysis

Water Immersion Recovery for Athletes: Effect on Exercise Performance and Practical Recommendations

Whole-Body Cryotherapy: Empirical Evidence and Theoretical Perspectives

Whole-Body Cryotherapy in Athletes: From Therapy to Stimulation. An Updated Review of the Literature

Compressive Treatments

Are Compression Garments Effective for the Recovery of Exercise-Induced Muscle Damage? A Systematic Review with Meta-Analysis

Bringing Light into the Dark: Effects of Compression Clothing on Performance and Recovery

Compression Garments and Recovery from Exercise: A Meta-Analysis

Dynamic Compression Enhances Pressure-to-Pain Threshold in Elite Athlete Recovery: Exploratory Study

Does external pneumatic compression treatment between bouts of overreaching resistance training sessions exert differential effects on molecular signaling and performance-related variables compared to passive recovery? An exploratory study

Psychological Factors and Social Support

Social Support and Health: A Review of Physiological Processes Potentially Underlying Links to Disease Outcomes

Social Psychology And Health

Does how you do depend on how you think you'll do? A systematic review of the evidence for a relation between patients' recovery expectations and health outcomes.

Compassionate Touch

Massage and Performance Recovery: A Meta-Analytical Review

Effectiveness of Sports Massage for Recovery of Skeletal Muscle from Strenuous Exercise

Physiological Responses to Touch Massage in Healthy Volunteers

Additional Resources

Complex systems model of fatigue: integrative homoeostatic control of peripheral physiological systems during exercise in humans

Is Self Myofascial Release an Effective Pre-Exercise and Recovery Strategy? A Literature Review

Does Electrical Stimulation Enhance Post-Exercise Performance Recovery?

Effects of Stretching Before and After Exercising on Muscle Soreness and Risk of Injury: Systematic Review

Delayed Onset Muscle Soreness: Treatment Strategies and Performance Factors

Recovery in Soccer: Part II-Recovery Strategies