Strength Training for Triathletes: Blending Anecdotal and Empirical Evidence to Improve Triathlon Performance

by

Kevin J. Le

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Triathlon is an endurance sport consisting of back-to-back swimming, cycling, and running. There are four popular distances: sprint (.75km swim, 20km bike, 5km run), Olympic (1.5km swim, 40km bike, 10km run), half-ironman (1.9km swim, 90km bike, 21.1km run), and ironman (3.8km swim, 180km bike, 42.2km run). Even at the shortest distances, elite triathlon performance requires excellent aerobic fitness (maximum rate of oxygen consumption and lactate threshold) and movement economy.\(^1\) Strength training, defined here as weight lifting targeted at primary movers of large muscle groups, is becoming popular as a means of improving performance. Empirical evidence shows heavy strength training to benefit endurance sport performance in laboratory settings. However, optimal training changes in the context of confounding variables of life, such as family and work, and the additional stress they create. The purpose of this project is to explore both the scientific and unscientific elements of triathlon training to aid triathletes in developing a plan for strength training (or none at all) to improve their performance.

Key Words: strength training, resistance training, weight lifting, triathlon

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Preface

All opinions in this text are products of personal knowledge and experience with triathlon, both of which stem from several years of training, racing, coaching, and education (undergraduate Kinesiology degree and self-guided reading). This is not an assertion of personal views as golden rules; they are only personal. However, read with an open mind, and this text may lead to seeing something in a different light and new realizations.

Introduction

This text is intended to be a discussion about strength training for triathletes. Here, strength training is defined as weight lifting to increase maximum force production and rate of force production within major muscle groups. Strength training does not refer to rehabilitative exercises like those found in physical therapy programs. This text reviews current scientific literature related to strength training and endurance sport performance, but it also considers abstract elements of triathlon that are not able to be evaluated in randomized controlled trials. It includes significant influence from practice—the art of coaching, training, and racing—and anecdote, two unscientific but important and highly-prevalent forces in endurance sport training and racing. This text is not a formal scientific review nor does it propose there is a single best way to strength train for triathlon. There are no example strength training programs included in this document, as there are plenty of free or inexpensive resources with adequate weight lifting routines. This work does include, however, guidelines on how to approach strength training, how much energy to put toward strength training, and general goals for different
levels of strength training. Through a combination of the abstract elements of triathlon training and scientific principles, this text is intended to inform athletes how they might take their personal needs into consideration in deciding what role strength training can play in their athletic pursuits.

Triathlon is a young sport full of contradictory opinions on how to optimize performance on race day. Because of its time demands and its complex nature as a combination of three sports, training can be considered as much of an art as it is a science. It can be argued other endurance sports are more informed by science due to greater simplicity (training a single sport vs. three) allowing for more applicable experimental results; however, it is difficult to apply the results of traditional research trials to triathlon with great validity because of the following factors. Research experiments take place in controlled laboratory settings with controlled variables and often reveal distinct, objective outcomes. However, countless variables impact both training and race-day performance for triathletes, and these interactions are impossible to dissect. For example, how does a high volume of run training impact the athlete’s ability to swim with proper technique? How does a subsequent bike workout after a run workout impact the potential adaptations that would follow an isolated run workout? Does replacing a swim/bike/run session with a strength training session yield better performance on race day? There are certainly no clear answers to these questions, and the answers likely differ between individuals.

The umbrella question governing all decisions related to optimizing training is: “What should I do right now to maximize my performance on race day?” Under this question falls many more specific questions. Some of them, related to this text, include
should I do more swim/bike/run volume or intensity? Is more always better? Should I lift weights, and how should I lift weights? Should I lift weights in addition to my endurance training or in place of a portion of it? Should I train through tiredness and fatigue, or should I rest? This text will demonstrate how much the answers to these questions can vary and are dependent on wide range of factors. The individual’s path to optimal athletic performance constantly changes with the confounding factors of everyday life. For example, a period of illness or injury alters the optimal sequence of workouts leading up to a race, or a few stressful weeks at work impacts personal motivation and changes the best path to maximum performance. Hopefully, reading this text will help athletes to think about their training and to create a plan for strength training suited to their own life.

**Challenges of Triathlon**

The individualism of triathlon training is rooted in the challenges posed by the need to be competent in three sports. Training three sports simultaneously creates questions on how to budget time and energy. It also creates uncertainty in how training should be structured due to the impacts of prior workouts on subsequent training within and between days. There is minimal scientifically-based information to direct the organization of training three sports to yield optimal adaptation and performance. The unlimited possible combinations of discipline and duration introduce countless variables, which are impossible to test in a controlled laboratory setting. There are so many technical skills and elements of fitness that can be developed in triathlon training that this becomes a large balancing act, consisting of working on weaknesses, capitalizing on strengths, and preparing to race.
**Time**

A survey of 83 elite triathletes and 25 coaches provides insight into how much elite triathletes train. The athletes in this study averaged approximately 25 km/week of swimming, 305 km/week of cycling, and 80 km/week of running (Fernandez, Acero, Lopez, & Pereiro, n.d.). While the authors did not record duration of training, it is estimated the total time to complete these distances would be 25-30 hours per week (7 hours for swimming, 15 hours for cycling, 7 hours for running). The elite athletes achieved peak volumes of over 40 km/week of swimming, 470 km/week of cycling, and 100 km/week of running (with peaks for each sport occurring on different weeks). On the contrary, age-group triathletes with full-time employment and other life commitments may average only 12-13 hours of training per week.

Retrospective studies show a large majority of elite endurance athletes achieving superior results by adopting a polarized training regimen with about 80% of training performed at low intensities and 20% at high intensities (Stöggl & Sperlich, 2015). For the aforementioned elite triathletes, this means 20-25 hours a week are dedicated to low intensity training. Age-group triathletes come nowhere close to these training volumes. Thus, a potential limiter of performance for age-group triathletes is simply the time they put toward training.

**Energy: The Stress Budget**

Fulfilling performance potential requires short-term and long-term mental and physical fortitude. It requires an open mind and the desire to achieve confidence and competence in every aspect of the sport. Colloquially, triathlon is said to be not a
destination, but a journey involving constant challenges that affect all areas of life. Jesse Kropelnicki, founder and head coach of QT2Systems and a USA Triathlon coach of the highest rank (Level III; achieved by less than 30 individuals in the USA), illustrates his “stress budget” concept in lay articles and at USA Triathlon coaching clinics. The ‘stress budget’ is the maximum amount of stress an individual can experience without it becoming counterproductive to success as an athlete. It encompasses everything in life, including employment, family, finances, and sport, and is very much related to time availability. Stress is not inherently detrimental, because it is a stimulus for growth, but there is only so much energy or effort that an individual can direct toward managing stressors. Excessive stress results in burnout, demoralization, and, ultimately, regression (J Kropelnicki, 2017).

Stress is dynamic and multifaceted with physical, mental, and emotional elements all contributing to an end-product: short- and long-term performance in all areas of life. In the context of triathlon training, strength training is an additional stressor composed of the physical stress of lifting weights and the mental stressors related to traveling to the gym, paying for a membership, fitting the workout into a schedule—thinking about an entirely new item within a training program. The daily requirements of strength training, such as commuting and completing the session, are short-term stressors. There is a significant long-term stressor associated with strength training too; workouts must be of quality and have consistency in order to provide optimal benefits. As with any kind of goal-oriented practice, lifting weights every other month will not create effective progress. Emotional stressors become relevant when the athlete starts to worry about missing workouts or feels anxiety when making sacrifices to make time for strength
training. It is a balancing act: how much stress from various areas of life yields the best triathlon performance.

One must also consider the individuality of perception of stress and distinguish between absolute and relative stress. Training load quantification measures an absolute stress, such as time spent training or miles run per week. However, 20 hours of training (absolute stress) may be perceived as easy to an elite athlete, whereas the same amount of training would be perceived as difficult to a beginner athlete (relative stress). Perception of stress changes over time, as the beginner athlete may progress to an elite status and now perceives a previous challenge as relatively easy.

Fortitude allows one to manage a large amount of stress, and differences in fortitude between individuals helps govern how much stress they can cope with without negative side effects. Those who succumb to small amounts of absolute stress will make minimal progress, while those who effectively manage large amounts of absolute stress will adapt and grow. Developing fortitude and resilience increases the size of the stress budget.

To summarize, an athlete’s ability to manage stress determines the size of their stress budget, and the size of the stress budget, along with its distribution between stressors, determines the athlete’s potential for success. The individual who makes the most efficient use of the largest stress budget has the greatest chance of achieving the high level of performance they have prepared for.
Limitations of Science: Confounding Variables, Emotions, and Interactions between Sports

Empirical evidence from randomized controlled trials (RCT) is an excellent tool for designing effective training. Countless studies that have evaluated short term (several weeks) adaptations to various kinds of workouts. Within endurance sports, for example, high intensity training (HIT) yields greater improvements in VO$_2$max and lactate threshold than does sustained low intensity training (Milanović, Sporiš, & Weston, 2015). In fact, a few sprints—totaling three minutes in duration—can provide the same physiological benefits as hours of high volume low intensity training (HVLIT) (Gibala et al., 2006). These results may suggest time is best spent training at high intensities, and training at low intensities yields inferior results. Lay articles in particular tend to interpret such experimental results

However, observational studies clearly show superior endurance sport performances in individuals who accumulate massive amounts of time training at very low intensities (Stöggl & Sperlich, 2015). Elite athletes spend thousands of hours over the course of their careers at easy efforts.

It is impossible to have long-term longitudinal studies comparing an intensity-based training plan to a volume-based training plan. Observational studies indicate it is the years of accumulated low-intensity mileage that give elite athletes their physiological capabilities (Seiler, 2010). Studies lasting 6 to 12 weeks will show relatively little adaptation with HVLIT and much more adaptation with HIT, but they do not address the sustainability of progress. They do not provide information regarding the long-term effects of either, nor can they incorporate the mental and emotional components of hard
training. Will the high-intensity-induced adaptations continue to occur at week 24, or will the athlete plateau and/or experience burnout by week 16? Does a HVLIT-based program have great success due to the long-term sustainability of its associated mental, emotional, and physical exertion?

Studies like that conducted by Gibala et al. occur in relative isolation of external variables. The athletes’ training plans are standardized and closely monitored, and the athletes are not training all three sports in multiple workouts per day. Such a study also does not address the potential detrimental effects of maximal cycling intervals on performing other workouts in a triathlete’s training regimen. Furthermore, in the real world, the extrinsic motivation provided by the researchers in the laboratory does not exist. Six weeks of sprint-based cycling workouts may yield superior results in the laboratory, but they may also cause psychological burnout when performed on the living room stationary bike due to the sheer discomfort of maximal effort. Sustainability is crucial in real-world triathlon training and is achieved via a delicate balance of taxing and restorative efforts. RCTs comparing various types of workouts simply do not address the emotional and mental components of endurance training—they, by definition, cannot.

For example, an athlete experiences fatigue from performing frequent high intensity bike workouts, and this fatigue interferes with his ability to swim with proper body position. Even though his bike fitness may be optimized by such sessions, the tradeoff with swim technique development may lead to non-optimal race day performance. Consider an athlete who has poor cycling endurance and running speed. Perhaps doing short, fast running intervals is the best possible way to improve the athlete’s running ability. But if these intervals cause excess leg or central nervous system
fatigue and interferes with endurance-focused cycling workouts, another tradeoff must be made.

Strength training has physical, mental, and emotional considerations like those of swim/bike/run training. If an athlete strongly dislikes strength training, they will need to draw on sheer willpower to deal with the time demands, discomfort, and physical effort of lifting weights. This is likely unsustainable due to the transient nature of behavior changes that draw from willpower, especially when the contribution of the behavior change (strength training) to the outcome (race performance) is difficult to quantify (Woolley & Fishbach, 2017). If the athlete enjoys lifting weights but has limited time for additional training on top of existing swim/bike/run workouts, adding in regular strength training sessions may be harmful if the stress budget is exceeded. Replacing a portion of swim/bike/run with strength training might improve performance, but this topic has not been well-researched in triathletes, especially in triathletes who are extremely time-limited and are doing minimal amounts of swim/bike/run.

**Individuality: History, Genetics, and Fortitude**

For most people, with so many skills to develop across the three disciplines, there will always be strengths and weaknesses. Athletic history, personality, and work ethic—individuality—are unique to each individual and determine the path to optimal race performance. Science is limited by its inability to determine the impact of individuality on the effectiveness of different types of training. Individuality creates room for a form of art—the abstract nature of deciding what is best for an athlete’s unique physiology and psychology.
Athletic history refers to the training an athlete has accumulated to present day. An individual who grew up swimming will have a solid foundation in swim technique, whereas an athlete who started swimming during adulthood will be heavily limited by technique. Former swimmers will not need to spend nearly as much time training their swim and can spend those resources on developing cycling and running abilities. A similar philosophy applies to other sports; athletes who grew up running can sustain greater volumes of running with relatively low risks of injury. Newer runners need to be more cautious when increasing run mileage.

Each athlete also has different genetics and fortitude. Genetics, similar to the concept of talent, in part determines the potential of an athlete and how quickly and effectively they can achieve their potential. Fortitude refers to the athlete’s work ethic, or how much effort they are willing to expend trying to improve. There are countless physical and psychological factors that impact both grit and genetics. Many factors are also impossible to quantify, such as pain tolerance, motivation, or the ability to deal with lack of motivation or stress. The best approach to designing triathlon training identifies these abstract elements of life and integrates them, whereas a training program that constantly conflicts with life will result in missed workouts and additional stress.
Strength Training Physiology and Potential Benefits

Physiological Demands of Triathlon Performance

Elite triathlon performance is marked by high aerobic capacity (VO$_2$max), lactate threshold, and movement economy (Sleivert & Rowlands, 1996). VO$_2$max is an individual’s maximum capacity for oxygen consumption during exercise. Lactate threshold refers to an exercise intensity at which an athlete transitions to a greater reliance on anaerobic metabolism as opposed to aerobic metabolism; exercising at an intensity greater than lactate threshold exponentially reduces time to exhaustion. Movement economy describes how much power or speed can be produced with a defined amount of oxygen; a more economical athlete can produce greater power with a lower demand for oxygen (Bassett & Howley, 2000).

Basic Muscle Physiology

Skeletal muscle is under voluntary control and allows for locomotion. For example, contracting the quadriceps extends the leg at the knee, and contracting the biceps flexes the arm at the elbow. Skeletal muscle fibers are typically categorized as Type I, Type IIa, or Type IIx fibers. Type I fibers are also known as slow-twitch fibers, and Type II fibers are also known as fast-twitch fibers. The following table describes characteristics of each type of fiber relative to each other.
<table>
<thead>
<tr>
<th>Type I (slow)</th>
<th>Type IIa (fast-oxidative)</th>
<th>Type IIx (fast-glycolytic)</th>
</tr>
</thead>
<tbody>
<tr>
<td>• High fatigue resistance</td>
<td>• Medium fatigue resistance</td>
<td>• Low fatigue resistance</td>
</tr>
<tr>
<td>• Highly aerobic energy production</td>
<td>• Moderately aerobic energy production</td>
<td>• Anaerobic energy production</td>
</tr>
<tr>
<td>• Low cross-sectional area</td>
<td>• Moderate cross-sectional area</td>
<td>• High cross-sectional area</td>
</tr>
<tr>
<td>• Low force production</td>
<td>• Moderate force production</td>
<td>• High force production</td>
</tr>
<tr>
<td>• Low rate of force production</td>
<td>• High rate of force production</td>
<td>• High rate of force production</td>
</tr>
</tbody>
</table>

(Gollnick, Armstrong, Saubert, Piehl, & Saltin, 1972)

Triathlon is an aerobically-demanding endurance sport and requires fatigue resistance, so faster race times are correlated with greater proportions of Type I fibers (Inbar, Kaiser, & Tesch, 1981). However, fiber type is not the most important determinant of success in endurance events, as athletes with a variety of proportions of fiber types have seen success. Other factors, such as aerobic capacity, lactate threshold, and movement economy, play large roles in determining one’s performance as well (Coyle, 1995). There is also debate over whether or not training can induce a physiologically-meaningful conversion of Type II fibers to Type I fibers within a muscle (Wilson et al., 2012). Regardless of fiber composition, performance can be significantly improved via adaptation of existing fibers. Endurance training improves capillary density, mitochondrial function, force production, and cross-sectional area of Type I fibers. Endurance training can also cause a shift in Type II fibers from the more anaerobic Type IIx to the more aerobic Type IIa (Hawley & Stepto, 2001).

The effect of strength training on skeletal muscle depends on parameters such as load (weight), number of repetitions, number of sets, and speed of contraction. Adaptations to strength training include increased muscle size (hypertrophy), strength,
endurance, and/or rate of force production and can be summarized by the strength-endurance continuum: fewer repetitions (1-6) heavy loads improve strength, many repetitions (15+) of light loads improve endurance, and rate of force production is improved by lifting with high contraction velocities (Schoenfeld, Peterson, Ogborn, Contreras, & Sonmez, 2015).

Popular weight lifting sources commonly state moderate repetitions (8-12) of moderately-heavy loads lead to greatest hypertrophy, while performing many repetitions with lighter loads do not yield hypertrophy. However, similar degrees of hypertrophy have been observed across the strength-endurance continuum irrespective of load provided the total volume of the workouts are the same across conditions i.e. 3 repetitions of 100 pounds vs. 15 repetitions of 20 pounds (Haun Cody T. et al., 2017). These observations lead to theories suggesting hypertrophy is governed significantly by total metabolic stress and muscle damage—lifting to closer to failure, therefore inducing high metabolic stress and muscle damage, may be more important than the weights used in yielding hypertrophy (Schoenfeld, 2010). However, reaching such metabolic stress and muscle damage with light loads takes much more time, which makes using heavier loads more efficient in achieving hypertrophy. A practical subjective measure of metabolic stress and muscle damage is how fatigued the athlete feels after the workout—an extremely demanding bout of weight lifting likely creates more hypertrophic stimulus, whereas a relatively unchallenging workout does not.
**Strength Training and Endurance Performance in Trained Individuals**

In the case of endurance sports, significant hypertrophy is not desirable due to the accompanied increase in body mass and therefore oxygen consumption. Greater body mass, lean or fat, is detrimental to endurance performance due to associated decreases in relative VO$_2$max (Maciejczyk, Wiecek, Szymura, Szygula, & Brown, 2015). Minimizing hypertrophy means minimizing metabolic stress and muscle damage while still generating enough stimuli to yield strength adaptations.

A large majority of scientific literature supports the use of heavy and explosive strength training to improve endurance sports performance. The performance gains resulting from strength training are linked to improvements primarily in exercise economy, not energy metabolism (Beattie, Kenny, Lyons, & Carson, 2014; Rønnestad & Mujika, 2014). To improve exercise economy, it is crucial for the athlete to lift near-maximal loads to create improvements in endurance performance; high-repetition low-load weight lifting is much less effective in trained individuals (Ebben et al., 2004).

Strength training does not improve VO$_2$max nor does it improve lactate threshold (LT) as a percent of VO$_2$max (O$_2$ consumption at LT divided by VO$_2$max). However, exercise economy, maximal velocity ($V_{max}$, maximal velocity at the end of an incremental treadmill test) and peak power output ($W_{max}$, maximal power output at the end of an incremental cycle test) do improve (Taipale et al., 2010). Because exercise economy increases (O$_2$ consumption at a given velocity or power output decreases), velocity and power output at lactate threshold also increase. Higher $V_{max}$ and $W_{max}$ values are indicative of improved anaerobic capacity and neuromuscular characteristics and
contribute to improved endurance performance (Baumann, Rupp, Ingalls, & Doyle, 2012).

Exercise economy is improved through various mechanisms. First, heavy strength training increases the force production of type I muscle fibers. An exercise at an intensity previously requiring activation of type II muscle fibers, due to force production demands, can subsequently be performed with a greater proportion of type I fiber activation, because the maximal-strength-trained type I fibers have been trained to produce more force (Rønnestad, Hansen, & Raastad, 2011).

Second, heavy strength training yields neuromuscular adaptations improving coordination and motor recruitment patterns. Through this process, the nervous system becomes more efficient by minimizing recruitment of fibers that do not contribute directly toward force production. This is hypothesized to improve endurance performance by reducing the number of muscle fibers required to achieve a given force output. Less active muscle fiber recruitment leads to a reduction in overall muscle fatigue in a given time. This has been demonstrated in a study of cyclists, where MRI and EMG analysis showed that increased maximum strength reduced the amount of activated muscle mass to produce the same absolute submaximal power (Bieuzen, Lepers, Vercruyssen, Hausswirth, & Brisswalter, 2007).

Heavy strength training and explosive strength training increase stiffness of the muscle-tendon system. Increased muscle and tendon stiffness increases elastic energy return during the stretch-shortening cycle of muscle while running. Runners with stiffer muscles and tendons, and therefore greater elastic energy return, have better running economy (Trehearn & Buresh, 2009). This mechanism does not provide benefits during
cycling, however, as the stretch-shortening cycle relies on the eccentric loading of muscle. Cycling is dominated by concentric contractions (Rønnestad & Mujika, 2014).

Similar mechanisms seem to benefit swimmers as well. Improved maximal force, rate of force production, and neuromuscular efficiency have been shown to improve distance swimming performance. Core strength plays a significant role in generating forward-propulsion during swimming too (Crowley, Harrison, & Lyons, 2017).

**Injury Rehabilitation and Prevention**

Strength training plays important roles in preventing and rehabilitating training-related overuse injuries. Athletes who have recurring tendon injuries will benefit from regular strength training, as resistance exercise increases the number and packing density of collagen fibrils in tendons. Resistance exercise also facilitates the restructuring of a healing tendon by encouraging the fibers to align themselves parallel to the direction of force (Brumitt & Cuddeford, 2015). Rehabilitation of some specific tendon injuries is most effective with loaded eccentric movements. Though the mechanisms behind eccentric rehabilitation are relatively unknown, collagen synthesis increases significantly following eccentric training (Langberg et al., 2007). Examples of eccentric exercises include calf raises applying both legs in a quick (1s) concentric phase and one leg in a slow controlled (4s) eccentric phase; and squats using the same technique of two-leg concentric, one-leg eccentric technique, similar to the calf raise.
General Health: Aging, Sarcopenia, and Bone Health

The strength training debate changes when considering older athletes and individuals with low bone density, particularly since general health is more important than endurance sport performance. Sarcopenia, the age-related decline in muscle mass, will eventually lead to strength limitations, and strength training helps maintain both muscle mass and bone density (American College of Sports Medicine et al., 2009). Truly-limited muscular strength does impair endurance sport performance, and it eventually affects the individual’s ability to carry out everyday tasks. Maintaining muscle mass with strength training reduces the risk of osteoporosis and the signs and symptoms of multiple chronic diseases. In general, strength training combats weakness and frailty and their debilitating consequences (Seguin & Nelson, 2003). An athlete in their forties or fifties might not be experiencing strength declines significant enough to cause symptoms but starting a strength training routine at their present age may set a foundation for improved health during older age.

Bone mineral density (BMD) is a concern for swimmers and cyclists. Athletes who spend a large amount of time swimming or cycling are effectively spending time with relatively unloaded bones. BMD decline is accelerated in these individuals and creates an increased risk for osteoporosis (Abrahin et al., 2016). Because strength training has positive effects on BMD, strength training should be a consideration in any swimmer or cyclist’s training program. Runners have higher site-specific BMD (lower limb bones) due to impact forces and the weight-bearing nature of the sport (Duncan et al., 2002), provided they have adequate nutrition. However, distance runners are still at risk for low BMD in the spine (Bilanin, Blanchard, & Russek-Cohen, 1989; Hind,
Truscott, & Evans, 2006). More research is needed to determine if distance running is a cause of low spinal BMD, as there are potentially-confounding implications of low body mass, inadequate nutrition, and lifestyle that are common among distance runners, especially females (Burrows, Nevill, Bird, & Simpson, 2003; Hind et al., 2006). To summarize, strength training plays an important role in maintaining general health and wellness and in contributing to BMD.

**Art: A Balancing Act**

Empirical evidence clearly suggests that heavy strength training improves endurance performance via increased movement economy. The question can be asked then, shouldn’t all triathletes lift heavy weights? The answer lies within the strengths, weaknesses, and non-sporting life of the athlete. Most triathletes are already time-constrained to the point they cannot accumulate optimal volume in each of the three sports. Trying to fit in two strength training sessions or replacing swim/bike/run workouts with strength training could possibly reduce performance, because the athlete is not training enough in the three sports that make up triathlon. Heavy strength training also comes with the cost and time requirement of going to the gym, both of which contribute to overall stress and spend part of one’s stress budget.

Furthermore, heavy strength training is hard. The athlete must consider if the benefit of strength training outweighs the negative impacts of its associated fatigue on swim/bike/run sessions. Fatigue from strength training, even if no delayed-onset muscle soreness is present, reduces endurance exercise performance and adaptations for up to 72 hours due to reduced neuromuscular drive. Furthermore, if the athlete has some level of
chronic fatigue due to strength training, even if at levels so low it becomes hard to
distinguish from swim/bike/run-induced fatigue, endurance development is likely
hindered (Doma, Deakin, & Bentley, 2017). A study with rowers showed athletes who
completed a modest amount of strength training (never lifting to failure) performed better
than athletes who performed a greater amount of strength training (lifting to failure)
(Izquierdo-Gabarren et al., 2010).

This makes strength training program design, or a lack thereof, a subjective and
abstract decision-making process. If high force production is a major limiter for an
athlete, then replacing endurance workouts with strength training could result in
improved performance. If an athlete has enough muscle mass and force production for
triathlon purposes, then adding strength training may be excessively fatiguing and
negatively impact more important endurance-focused workouts. Therefore, the debate
exists in regard to how much strength training constitutes enough in the sport of triathlon.

Elite coach Jesse Kropelnicki applies the concept of lean body mass index (BMI),
which is the BMI of an individual calculated using calculated body weight based on ideal
body composition for racing. Lean BMI is a representation of how much muscle an
individual has. A high lean BMI value means the athlete likely does not have a strength
limitation and vice versa for low lean BMI. His anecdotal experience suggests female
athletes perform best at lean BMI of 20, and males at 21. To find lean BMI, the athlete
first undergoes a body composition test to estimate body fat percentage (BF%). BF% is
used to calculate existing fat mass and subsequently how much fat mass must be lost to
reach ideal body composition. The value for target fat mass loss is subtracted from total
body weight to yield lean body weight, and lean body weight is used to calculate lean
BMI with the same equation that would be used for normal BMI (Jesse Kropelnicki, 2011).

In the context of single-sport athletes who might not carry as much fatigue due to lower overall training volume compared to triathletes, adding strength training might often be more feasible and appropriate. It may also be easier for single-sport athletes to reach adequate volumes of training in their respective sports, whereas time-constrained triathletes must juggle training for three sports. One must also consider if the athlete enjoys strength training. If the athlete has no desire to lift weights and is not significantly limited by their strength, then they are probably better off spending the time on swim/bike/run. If the athlete perceives benefit and enjoys strength training, then it may be worth considering.

**If Strength Training Is Desired: How-To**

Many training resources portray strength training as an all-or-nothing approach, but this is unhelpful for athletes who have only twenty minutes a week for strength training. The top result of a “triathlon strength training” Google search reveals Mark Allen’s (six time Ironman World Champion) recommended weight lifting program of twelve exercises performed twice a week throughout the entire year (Allen, n.d.). Joe Friel’s popular book, *The Triathletes Training Bible*, outlines a periodized weight lifting program consisting of two to three sessions in the gym per week (Friel, 2016). It is presented in a very structured format without any suggestions for alternatives. Both Allen’s and Friel’s programs consist of periodized year-long cycles with significant progressions every several weeks.
Athletes with little time to lift weights may benefit from rethinking the traditional strength training periodization reported in both popular training resources and scientific literature. Good training involves dynamic year-to-year consistency in addition to within-year consistency. There are peaks and nadirs with adjustments being made along the way due to unforeseen life occurrences. However, the general trajectory is steady progress. Athletes should think about strength training with a similar mindset and utilize a conservative long-term approach based on consistency, gradual progression, and flexibility.

Traditional strength periodization principles that are often found in endurance-focused strength training books are similar to the following:

1. Adaptation Phase: low weights and a high number of repetitions (15-20) are used for four to six weeks to build general strength in preparation for heavier loads.

2. Transition Phase: the weight is increased significantly over 2-4 weeks while the number of repetitions is decreased (6-12) to transition from light loads used in the adaptation phase to the heavy loads of the maximum strength phase.

3. Maximum Strength Phase: the weight approaches near 1-repetition maximums and repetitions are low (3-5). A large amount of rest (3+ minutes) provides full recovery in order to lift heavy loads with quality. The maximum strength phase lasts until competition season demands increased emphasis on freshness and race-day performance.
4. **Power or Maintenance**: after the maximum strength phase, some sources will instruct athletes to move to a power phase in which loads are decreased and emphasis is placed on the speed of contraction to maximize power. Plyometric exercises are the classic example of power training. Other sources suggest moving straight from maximum strength to in-season maintenance in which the athlete will still lift heavy loads but in significantly reduced volumes (i.e. fewer sets) to maintain strength while minimizing fatigue.

These traditional principles fall under a linear periodization format, which makes logical sense on paper. Consider, however, the following questions: what if an athlete misses two weeks of strength training due to other life commitments? Does this periodization structure need to be followed every year in this order? What other options exist?

First, general foundational strength is necessary before performing any sort of heavily-loaded or advanced movement. Not only is this important for injury prevention, but building stability first actually increases subsequent lifting performance (Hammami, Granacher, Makhlouf, Behm, & Chaouachi, 2016). In other words, an adaptation phase should be a part of any strength training program if the athlete has not been regularly weightlifting prior to beginning the program.

After foundational strength has developed, athletes have much more flexibility than generally described in popular triathlon training books (explained later). The goals of strength training remain similar—increase maximum force production and/or rate of force production while minimizing muscle hypertrophy. This means the athlete should still aim to perform few repetitions at high weight in compound movements or power-focused explosive exercises. However, the athlete does not have to be fixed in a rigid
linear periodization plan; the plan can be constantly evolving to fit the athlete’s life and schedule.

This type of “evolving” strength training program is essentially undulating periodization. Instead of having training phases with distinct repetitions and weights, the athlete constantly switches between adaptation-, transition-, maximum-strength-, and power-type exercises depending on what is most appropriate at that time. For example:

- If the athlete is emerging from a period of time with minimal weightlifting and lacks foundational strength and stability, adaptation is necessary.
- If the athlete has been in a maximum strength phase but encounters two weeks with no lifting, they could return to a couple of weeks of transition-type repetitions and weights to ease back into near-maximum weights.
- If the athlete has two busy upcoming weeks at work and can lift only once per week, maximum strength and power can be maintained by doing a couple of specific exercises for each of those two workouts. After those two weeks, the athlete can resume lifting two or three times per week.
- If the athlete has a few races spaced one month apart and wants to minimize weightlifting-induced fatigue while maintaining strength and power, the weeks can be structured in the following cycle: race, maximum strength, power, maintenance.

A flexible or undulating weightlifting program is not inferior to a linear program. An undulating program may actually yield better results due to the ability to allocate different types of sessions where they are most appropriate (Harries, Lubans, & Callister, 2016). This flexibility allows the athlete to optimize adaptation and to minimize fatigue.
when needed, and there are few to no downsides of alternating between types of
weightlifting (i.e. switching between heavy lifting and explosive training within a season
(Hartmann et al., 2015).

If strength training sessions are skipped for several weeks for various reasons, it
may be risky to resume strength training with the same weight load, as some stability or
technical skill may have been lost. If this is the case, the athlete can resume strength
training with lighter loads (similar to adaptation weight) to re-establish stability before
progressing back to heavier loads to minimize injury risk. Missing a few weeks of
strength training is a not significant hindrance if long-term consistency is maintained. An
inactivity period of up to three weeks does not significantly decrease muscle strength or
impair subsequent adaptation to resumed strength training (Gentil et al., 2015;
Ogasawara, Yasuda, Sakamaki, Ozaki, & Abe, 2011). Missing more than three weeks
will result in a detraining effect. However, previous strength training facilitates retraining
following a period of retraining, and any strength losses can be regained much more
quickly (Lee, Hong, & Kim, 2016). It is hypothesized the rapid retraining is a result of
“muscle memory” is a result of the fact that the number of nuclei in muscle cells
(myonuclei) increase with strength training. During disuse and atrophy, these myonuclei
are not lost and may contribute to subsequent adaptation (Bruusgaard, Johansen, Egner,
Rana, & Gundersen, 2010). Thus, the benefits of strength training can be improved on or
maintained year to year even if there are periodic breaks from strength training. There is,
of course, a line that must be drawn for how much strength training is enough to yield
desired results, as there is a minimum threshold of training volume and intensity that
must be crossed to cause adaptation (Schoenfeld, 2013).
Summary

There is no single correct or perfect training program. It is up to the athlete or coach to analyze the pros and cons of adding strength training and, if strength training is performed, to create a strength training program that fits the athlete’s life. The following sections provide a summary of approaching strength training for triathletes, with the caveat that there are clearly endless modifications for any suggestions. It is ultimately a summary of my personal views on strength training for triathletes that integrates science, art, and anecdote to try to answer the following question: what should I do right now to maximize performance on race day?

Questions to ask:

- Does the athlete want to strength train?
- Is the athlete doing adequate swim/bike/run volume?
- Is the athlete strength-limited or experiencing age-related bone or muscle degeneration?
- Does the athlete have enough time to add in strength training?

See the flow chart for a visual reference on the decision-making process.
Guidelines for Levels of Focus

High focus

- Dedicate an adequate portion of available stress and energy to strength training in order to perform high quality strength workouts
  - Reduce swim/bike/run volume and intensity to avoid being fatigued going into strength workouts
  - Maintain high consistency (2-3 times per week) by prioritizing strength workouts over swim/bike/run workouts when overall training time needs to be reduced
- Build stability before hypertrophy, maximum strength, and power
  - Adaptation (many repetitions, low weights) before maximum strength (few repetitions, heavy loads)
  - Resume with adaptation-type lifting following any breaks
    - Develop good technique before high effort and heavy weights
- Aim for muscle hypertrophy until lean BMI increases to ~21
  - During strength workouts, lift until near-failure without compromising form
  - Focus on compound movements that apply to swim/bike/run
    - Squat, deadlift, lunge, bench press, pull up/lat pull down, seated row
- Eat a large amount of protein (2.0 grams per kilogram of bodyweight per day) while maintaining a mild caloric surplus (300-500 calories per day) to maximize muscle hypertrophy (Stark, Lukaszuk, Prawitz, & Salacinski, 2012)
• Move to maximal strength and power after target lean BMI is reached

Moderate focus

• Strength training has a similar priority to swim/bike/run workouts
  ○ During times of high stress or low time availability, reduce both strength and swim/bike/run workouts

• Build stability before hypertrophy, maximum strength, and power
  ○ Adaptation (many repetitions, low weights) before maximum strength (few repetitions, heavy loads)
  ○ Resume with adaptation-type lifting following any breaks
    ▪ Develop good technique before high effort and heavy weights

• Lift to maximize strength while keeping hypertrophy minimal
  ○ Lift at a perceived effort of moderate challenge/fatigue during workouts
  ○ Lift heavy weights close to 1-repetition-maximums with plenty of rest (i.e. 5x3 squats with 3-5 minutes rest)

• Balance swim/bike/run-induced and strength-training-induced fatigue

• Eat a moderate amount of protein

Low focus

• Train mindfully and be ready to make adjustments
  ○ The subsequent days of training are just as important as the present day
▪ If significant heavy lifting today feels like it will compromise future training with excess fatigue, reduce the volume and intensity of the workout

▪ Skip strength workouts during times of high stress or low time availability

• Build stability before hypertrophy, maximum strength, and power
  o Adaptation (many repetitions, low weights) before maximum strength (few repetitions, heavy loads)
  o Resume with adaptation-type lifting following any breaks
    ▪ Develop good technique before high effort and heavy weights

• Minimize hypertrophy and fatigue
  o Stop sets significantly before the point of failure
  o Lift to a perceived effort of low to moderate challenge
  o Low overall lifting volume and physical stress
    ▪ Finish feeling strong and invigorated, not sore and tired
  o Lift moderately heavy weights close to 3-repetition-maximums with plenty of rest (i.e. 5x3 squats with 3-5 minutes rest)

• Eat a moderate amount of protein
References


Lee, S., Hong, K.-S., & Kim, K. (2016). Effect of previous strength training episode and retraining on facilitation of skeletal muscle hypertrophy and contractile properties


https://doi.org/10.3389/fphys.2015.00295


https://doi.org/10.1519/JSC.0b013e31818eaf49

https://doi.org/10.1519/JSC.0b013e318234eb6f

https://doi.org/10.1177/0146167216676480