WHY WEIGHTED BALLS WORK

YOU CAN THROW HARDER AND REDUCE YOUR INJURY RISK

Chapter One

Training Matters: Why Building Velocity is Important

The idea that injury and performance lay on two ends of a scale is antiquated and has no scientific basis.

Velocity: the critical factor of pitching success

Fastball velocity is the floor of your performance ability. Elite college and pro coaches complain about pitchers having terrible command or getting hurt because all of the pitchers they have throw hard.

High-level coaches are not looking for an 82-84 MPH strike-thrower. If your goal is to play at that level, you need the tools to get a look to compete there.

By way of example, let's consider two high-school varsity pitchers.

Pitcher A has plus high-school velocity (sits 92+) with average command and will struggle to throw strikes.

Pitcher B has average high-school velocity (77-79) but plus command and can throw 3 pitches for strikes.

While they might have similar results, similar ERAs and make the all-city team, our experience training pitchers shows that Pitcher A is very likely to get many more offers from higher-quality colleges. He might even be a late-round draftee.

Why? Pitcher A has next-level Ability.

Maybe those coaches don't like the 97 MPH guy who has zero idea where it's going, but they want that guy to be 92-93 MPH with average or better command. 92-93 MPH is *really hard*. Not a lot of guys are cruising at that velocity.

Fastball Velocity
Here is a chart of fastball velocity from 2003-2015 at the Major League level.

Season	FB%	FBv
2003	63.8 %	89.9
2004	62.6 %	90.1
2005	61.9 %	90.1
2006	61.1 %	90.5
2007	60.6 %	90.3
2008	60.7 %	90.7
2009	59.7 %	91.2
2010	58.7 %	91.2
2011	57.8 %	91.5
2012	57.6 %	91.6
2013	57.8 %	91.7
2014	57.7 %	91.8
2015	57.8 %	92.0

Average fastball velocity increased from 89.9 MPH to 91.7 MPH since 2003, but the percentage of fastballs thrown has dropped significantly!

Increasingly, to compete at the highest level, you have to throw harder, *and* you have to throw off-speed and breaking pitches more frequently, *and* those have to be better.

If you limited the sample to relievers alone – one of the fastest ways to get to the big leagues – you see just how hard you have to throw if you are coming out of the bullpen:

Season	FB%	FBv	SL%	SLv
2003	65.4 %	90.7	16.1 %	82.2
2004	65.1 %	90.8	17.0 %	82.7
2005	64.3 %	91.0	18.3 %	82.8
2006	63.5 %	91.3	19.5 %	83.0
2007	62.1 %	91.1	19.3 %	82.6
2008	62.4 %	91.4	19.8 %	82.8
2009	61.2 %	91.8	17.8 %	82.9
2010	61.4 %	92.1	17.7 %	83.2
2011	60.6 %	92.3	18.0 %	83.2
2012	60.9 %	92.5	18.2 %	83.0
2013	60.6 %	92.5	17.8 %	83.2
2014	60.3 %	92.5	17.3 %	83.3
2015	59.7 %	92.8	18.7 %	83.6

This chart includes all the soft-tossing lefties coming out of the pen – if you limited it to right-handed relievers, the numbers would be higher.

To Compete At The Highest Levels…

Velocity is king.

Coaches and talent evaluators at the next level want to see: *either* that a pitcher's current talent level maps to other athletes at the higher level who are successful *or* that in their estimation the pitcher has a good shot of reaching that level in a short time frame. Returning to Pitcher A and Pitcher B, for Pitcher B, that is not the case. The list of good college pitchers throwing low 80s is very short.

The coaches who prioritize pitch mix and command over velocity are the coaches who have the luxury of having lots of pitchers with average or above velocity, or are amateur pitching coaches who have no idea how to train velocity.

To simplify the outcomes, here is a *very scientific* matrix that illuminates likely outcomes based on velocity and command:

	Throws 84 MPH	Throws 94 MPH
Bad Command	College walk-on	Minor/major college scholarship
Good Command	Minor college scholarship	Mid-round or better draft pick

But, If I Throw Harder, Am I Going to Get Hurt?
There is a common misconception that pitchers who throw harder automatically increase their risk for injury. As we'll explore, that simply isn't the case if done correctly.

To start to understand how training reduces your injury risk, we'll need to take a look at the mechanisms for injury in baseball pitchers in the first place.

Chapter Two

What are the mechanisms for injury in pitchers?

Introducing the Basics of Stress Response

In the world of physical therapy, there is a simple yet insightful theory that describes the response of any biological tissue to physical stress, the Physical Stress Theory [1]. According to this theory, there is a predictable continuum of responses a biological tissue can exhibit after experiencing physical stress.

The biological tissue types most relevant to baseball include muscles, tendons, ligaments, and bones. Physical stress simply means force applied over a specified area of the body.

First and foremost, the Physical Stress Theory assumes that there is a normal level of physical stress experienced by any biological tissue on a day-to-day basis. An example of normal stress for a typical human would be compression of the primary bones of the legs during walking.

When a specific tissue type experiences its normal level of stress, it maintains its normal strength and stress tolerance. In general, humans walk every day and this walking helps maintain the strength of the leg bones.

Sometimes a tissue type experiences less stress than normal for an extended period of time. When this occurs, biological tissue actually atrophies and experiences a decrease in strength and stress tolerance. An example of this can be seen when arm bones and muscles are placed in a cast for an extended period and become noticeably weaker. In older adults, tissues start to break down when levels of daily activity substantially decrease.

Biological tissue can also increase in strength and stress tolerance. According to the Physical Stress Theory, tissue types increase in strength and stress tolerance when they experience stress that is greater than normal. A prime example of this can be seen when a muscle increases in size and strength in response to increased resistance training.

It's very important to understand that positive adaptation to increased stress can occur in all tissue, including ligaments and tendons. The Achilles tendons of sprinters, in particular, have been studied and it has been shown that they increase in stiffness due to the increased demands on the tendons during running [2]. This same type of adaptation likely occurs in the elbow tendons and ligaments of pitchers [3-5].

How Injuries Occur

So if increased stress causes positive adaptation, how does injury occur?

Tissue injury occurs when biological tissue experiences a stress level that is *much* greater than normal. And this can mean lower magnitude stress over an exceptionally long period of time, or an excessive magnitude of stress that occurs once. Physical stress up to a certain threshold causes positive adaptation, but then once the threshold is exceeded; tissue can start to break down. The threshold between positive adaptation and injury is primarily determined by the fitness of the tissue in question.

It is easy to see that the baseball pitching motion places incredible physical stress on many different tissues of the body, especially at the shoulder and elbow. The muscles, tendons, ligaments, and bones of baseball pitchers experience stress levels that are much higher than a typical human will ever see in his or her lifetime.

If an inactive person were to go out and instantly throw a 95 mph fastball, he or she would probably immediately injure a shoulder or elbow tendon or ligament because these are typically the weakest links.

However, professional pitchers are able to regularly throw 95 mph without breaking down. How is this possible?

Adaptation as a Response to Stress

The bodies of athletes who have been pitching for years have adapted to the rigors of the extreme baseball pitching motion. But even professional pitchers do experience injuries. Though their bodies have adapted to handle increased physical stress, it is still possible for the pitching motion to cause stress that exceeds the injury thresholds in some of the more vulnerable areas of the body.

Thus, if you want to understand a pitcher's risk for injury, you need to understand three key factors: 1) the current fitness of his or her tissue; 2) the amount of force being applied to the tissue by the pitcher's throwing mechanics; and 3) the specific anatomy, or structure, of the at-risk body parts.

Fitness Factor

Fitness can be described with a variety of words – strength, endurance, or conditioning – but we're using it to cover all of those concepts. When we say a pitcher has poor arm-related "fitness," it generally means his or her tissue has a low injury threshold. This can be due to insufficient muscular strength, low muscular endurance, poor soft tissue quality, etc.

It is not easy to assess tissue fitness. To do so, it requires monitoring many areas of a pitcher's training, including what a pitcher eats, does in the weight room, does outside for his or her long toss/throwing program, and how much he or she pays attention to rehab/prehab.

As an example, a pitcher with chronic elbow-related issues might have poor forearm muscle fitness. These muscles might not have adequate strength or endurance. Strengthening the muscles in the forearm that attach to the elbow can help reduce the load on the anterior bundle of the ulnar collateral ligament (UCL). This is the part of the ligament most often injured in pitchers. When the UCL is injured, it typically requires the dreaded Tommy John ligament replacement surgery and a year or more of recovery and rehabilitation.

Mechanical Factor

The specific body movements utilized by a pitcher to throw a baseball, i.e. his or her pitching mechanics, determine how physical stress is distributed throughout the different tissues of the body during pitching. Mechanics can be thought of as the force application techniques a pitcher uses to accelerate the baseball.

Mechanics are very difficult to assess with the naked eye. It is best to assess pitching mechanics by recording and recreating them with high speed video, or in three-dimensions using marker motion capture, markerless motion capture, or inertial measurement units (aka IMUs; which are similar to the sensors in iphones that detect portrait vs. landscape orientation).

A typical analysis of mechanics will report both joint movements and joint loads.

However, it's important to note that even with a three-dimensional reconstruction of a pitcher's mechanics; there are two primary confounding factors that prevent you from knowing everything about a pitcher's injury risk by simply observing the mechanics.

● Lab vs. Game Setting: Kinetics (joint loads, forces, torques) and kinematics (angles, velocities, accelerations) of a baseball pitcher in a lab when he's wearing sneakers and has a bunch of sticky reflective globes on his body are not necessarily the same kinetics and kinematics experienced in a real game situation.

Example: A pitcher in an artificial setting may be throwing 10-20% slower than he or she would in a game when fully adrenalized and wearing actual game clothing… So what are you really learning in the lab setting?

● Equivalent Joint Loads Aren't Equal: Let's say you have two pitchers who have identical peak shoulder internal rotation torques. What can you determine from this? Well, not a whole lot – you can't say that the infraspinatus is receiving 10 Newton-meters of torque, because that type of specificity is not yet available. A lot of factors contribute to this – lateral trunk tilt, shoulder abduction, the timing of the peak force, actual weight of the humerus, etc.

Despite the difficulty involved in interpreting the effects of different mechanics, one thing can be said with certainty. Lower stresses are better if the achievement of these lower joint and tissue loads do not compromise performance.

Pitching mechanics should be monitored and optimized for maximum performance and minimum tissue loading.

Anatomical Factor

In addition to tissue fitness and pitching mechanics, there are also subtle variations in pitcher anatomy that influence injury risk.

For example, a pitcher can have a hypermobile elbow joint (e.g. a double-jointed elbow), that causes increased laxity around the elbow. Unlike laxity in the shoulders, laxity in the elbow is a very bad thing! Pitchers want a very stable elbow. The UCL's entire function is to keep the elbow together as it is literally pulled apart during the pitching delivery.

Pitchers who throw more as a young athlete can develop humeral retroversion – a slight twist in the bone of upper arm. This is an example of an osseous adaptation that occurs in response to the stress repeatedly applied by the pitching motion to the humerus.

Humeral retroversion is not necessarily a bad thing. Many researchers and exercise scientists think it's a necessary adaptation in baseball pitchers that allows for greater arm range of motion. Excessive throwing limitations as a kid can impede adaptations such as humeral retroversion that likely help pitchers safely throw 90+ MPH.

As another example, pitchers overwhelmingly have Type I (flat) acromions, which allow for more room in their shoulder joints. Most athletes with Type II (curved) and Type III (hooked) acromions simply don't go on to pitch professional baseball because they are at risk for major soft tissue injuries.

Assessing Risk for Tommy John Surgery

In general, it is impossible to accurately assess a pitcher's risk for injury without considering fitness, mechanics, and anatomy. And this is especially true when assessing the risk for a UCL tear and subsequent Tommy John surgery. A pitcher can remain injury-free with poor fitness if his or her mechanics do not excessively stress the elbow. Conversely, a pitcher with great mechanics can have chronic elbow problems if his or her elbow fitness is insufficient.

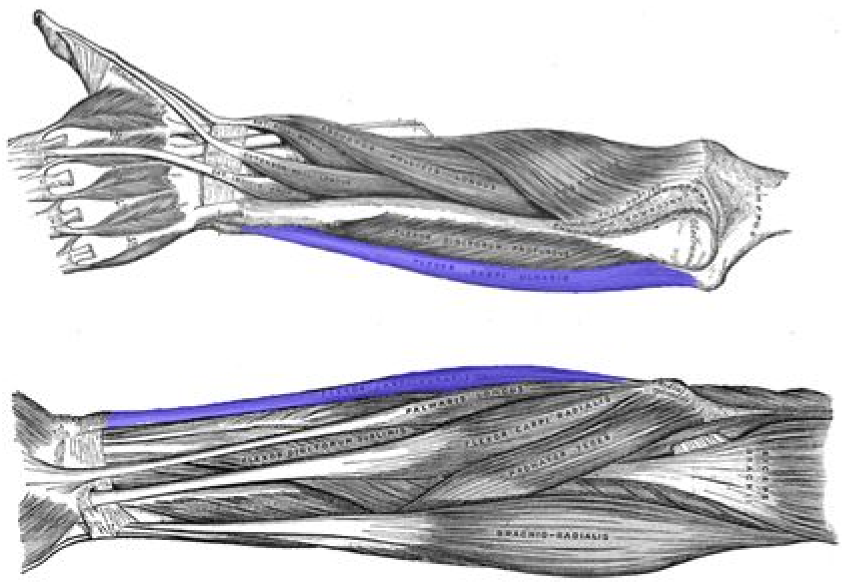
Please note that insufficient fitness in pitchers can mean imbalanced fitness. A pitcher can be in the top 1% of all athletes with respect to core and leg fitness, but if elbow muscle strength is in the bottom 1%, an elbow injury is likely inevitable.

A good throwing program should address areas of general fitness but absolutely must have a plan for arm-specific fitness.

In recent years it has become common to record mechanics in three dimensions and use the total elbow load, or varus-valgus torque, to assess a specific pitchers risk for a severe UCL injury.

Discussion of UCL Anatomy and Elbow Loading

The UCL is basically a tiny band that connects the humerus to the ulna, and it is practically impossible with existing methodologies to accurately determine UCL loading when only the total elbow load is considered. This ligament is only a few centimeters in size and it is in close proximity to many muscles and other soft tissue. It is loaded (i.e. it feels a force that causes stress) when it is stretched, similar to an elastic band. The image below shows the musculature of the left forearm. The UCL is hidden beneath the highlighted muscle near the elbow.



There are more than 10 muscles that cross the elbow [6], and when we only consider the total elbow load, we really have no way of calculating how any of these muscles are individually affecting the load on the UCL during a pitch. Scientists have used experiments in cadavers to show that the muscles on the inside of the elbow (the medial side) can relieve a load on the UCL [7-9]. The problem is these experiments cannot yet be replicated in living subjects.

Additionally, the bones of the elbow also provide substantial stability. Back in 1983, Dr. Morrey and Dr. An reported that just the bones and the joint capsule can support upwards of 40% of an applied elbow load [10]. However, this study was also completed in cadavers and muscles were not considered because the cadaver muscles were dissected.

Therefore, it remains unclear how the total elbow load relates to the specific load on the UCL. For a given elbow load, the stress on the UCL could be really high if the muscles and bones are not very fit, or it could be really low if the muscles and bones are exceptionally fit.

So any assessment of injury risk should include an assessment of fitness and anatomy as well as mechanics.

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Chapter Three

Can a pitcher concurrently reduce injury risk and improve velocity?

Why the Throwing Harder Does not Necessarily Mean Increasing Injury Risk

Many believe that increasing a pitcher's velocity also necessarily increases the pitcher's injury risk. This is a myth.

This misconception has been perpetuated because, across a population of randomly-trained pitchers, increased velocity may very well mean increased injury risk. Force equals mass times acceleration. Thus, with all things being equal, increased acceleration of the baseball during the pitching motion could lead to increased force, and stress, on biological tissue. And increased force on tissue could mean increased injury risk.

However, this assumes that the stress tolerance and strength of the more vulnerable tissue (e.g. the tissue of the elbow) remains constant as the velocity is increasing. It also assumes that the joint loads imposed by the mechanics scale up with the velocity.

But that does not need to be the case.

Injury risk reduction and velocity improvement do not need to be competing goals. There are effective ways to increase velocity and also considerably improve the fitness of at-risk tissue. Furthermore, it is very possible to make mechanics more efficient, such that the loads on the more vulnerable joints do not dangerously scale up as velocity increases.

Unfortunately, if a pitcher is not properly trained, tissue fitness can lag as velocity is increasing and gains in velocity can be accompanied by dangerous gains in valgus torque on the elbow.

Baseball velocity is the output of a complex series of biomechanical events and therefore an improvement in any number of areas can cause a velocity bump. A pitcher can increase his or her velocity by focusing on core and leg strength alone. A pitcher can even increase velocity simply by getting taller during puberty, which allows for throwing on a more downward plane.

But the key to safe velocity gains is to balance velocity improvements with concurrent improvements in tissue fitness and pitching mechanics. A pitcher can aggressively attack the dual goals of reduced injury risk and increased velocity through an intelligent combination of different training modalities.

The Role of Resistance Training and Ballistic Training in Improved Pitching Performance

Academic research shows that traditional resistance training and ballistic training with implements of various weights can significantly increase velocity. Peer-reviewed studies have also shown that improving the fitness of shoulder and elbow muscles (as is accomplished by a well-designed resistance and ballistic training regimen) can reduce injury risk at these more vulnerable joints.

One study on velocity enhancement compared more deliberate resistance exercises and more explosive plyometric exercises to a control group that did not undertake the resistance training. The researchers found that all resistance-trained experimental groups significantly increased their pitching velocity by approximately 2% over 6 weeks compared to the control group [1].

Balanced resistance training throughout the body likely improves velocity because it causes muscles to get bigger and stronger (i.e. experience hypertrophy). Stronger muscles produce more power, and therefore can impart more force on a baseball in a given amount of time.

Several studies have been published showing that significant velocity improvements can also be made through the use of ballistic exercises with both overweight and underweight implements [2-4].

Exercise specificity is essential in athletic training [5], which means that that to improve the strength of pitching muscles; a pitcher needs to perform exercises that have similar movement patterns to pitching. Throwing overweight and underweight baseballs accomplishes this.

In academic studies on ballistic training, velocity gains of more than 6% were observed over 6 to 12 weeks [2-4]. The ideal pitching program incorporates a mixture of both overweight and underweight ballistic training modalities.

Note that across the above peer-reviewed research on velocity enhancement, no injuries were reported. In fact, the injury risks for the studied pitchers were more than likely reduced by their workout regimens.

A study completed in high school pitchers explicitly showed that baseball-specific shoulder resistance training improved the muscular endurance of posterior shoulder muscles [6]. Shoulder muscular endurance is a key parameter known to be associated with improved shoulder function and reduced injury risk.

Additionally, resistance and ballistic training of elbow muscles can reduce injury risk at the elbow. Cadaver studies have shown that increasing the load supported by the muscles of the forearm can reduce the load supported by the UCL [7-9]. And this result was supported by a published computer simulation of an actual pitch thrown by a living subject [10]. In the simulation, it was shown that by increasing parameters associated with muscle strength and power, it was possible to actually eliminate dangerous UCL loading.

Of the muscles in the forearm, the flexor-pronator muscles get the most attention in baseball circles. They get the most attention because they reside in similar locations to the UCL on the body. Both the forearm flexor-pronators and the ligament originate on the inside (the medial side) of the bone of the upper arm (the humerus). Thus, when the muscles are contracting, they are very likely absorbing force that would otherwise be damaging the UCL.

And forearm muscles should not be the only focus… all muscles crossing the elbow are critical to protecting the vulnerable elbow ligaments. A contraction in any muscle crossing the elbow will result in increased compression of the joint. In general, a more compressed joint is a more stable joint.

So, in summary, increasing muscle endurance and strength through resistance and ballistic training can both improve velocity and reduce injury risk at the shoulder and elbow. These different training modalities expose muscles to increased duration of use and progressively increasing loads, which in turn cause positive tissue adaptation.

Overuse vs Increased Use and Muscle Adaptation

'Overuse' is being blamed for the eruption of Tommy John surgeries among baseball pitchers. Consequently, people in baseball have become hyper-focused on preventing overuse of the pitching arm. This has led to pitch counts, inning limits, and training guidelines that are more restrictive than ever before.

And yet UCL injuries continue to mount.

Usage restrictions are not helping because teams don't really know where the line is between 'increased use,' which causes positive adaptation, and 'overuse,' which causes injury. As a result, in trying to protect against overuse, teams may be going too far in the wrong direction and severely undertraining their pitchers.

Without adequate training, the body is unprepared for the rigorous demands of a regular pitching schedule. A pitcher should not be so afraid of overuse that he or she never pushes the body's limits. As stated many times in this document, responsible overloading is necessary for tissue adaptation.

Muscle tissue is one of the most adaptable tissue types in the body. Muscles have the ability to quickly (relative to other tissues types) adapt to situations of increased use and loading [5]. A single muscle is made up of many muscle fibers, and almost everything about each individual fiber can adapt, including its size, strength, speed, and endurance.

This means that a pitcher should expose his or her muscles to both increased duration of use and increased loading to increase both the endurance and strength of muscle tissue. Pitching requires both adaptations.

It seems that most training regimens for pitchers do include exposure to increased duration of use. A typical training regimen will have a pitcher slowly increase the amount of pitches in a session and/or the frequency of sessions. This type of training should increase muscle endurance… but it may not adequately increase muscle strength.

As a rule, the body adapts to most efficiently accomplish what is demanded of it [5]. So if extra strength is not needed to accomplish the task at hand, the body may lose the extra strength capacity because it is not needed and therefore it is not efficient to maintain it.

Unfortunately, this phenomenon could be manifesting itself in pitchers who follow a typical training plan with a regulation baseball.

For example, a typical training regimen for a pitcher could involve going out every five days and throwing up to 100 pitches, with a few shorter side sessions mixed in. If exposed to this usage pattern, it is likely that the pitcher's body would adapt to most efficiently throw the 100 pitches every five days.

So then what would happen during a critical game when adrenaline is pumping and the pitcher needs to throw 115 pitches at game-level intensity? What would happen when there are no outs in the bottom of the ninth and a guy on third so the pitcher needs to reach back for a little extra to get a key strikeout?

In the above situations, the pitcher's body would likely not have the maximum strength capacity to sufficiently handle the extra effort, and therefore more vulnerable tissues would be at increased risk.

The crucial component that seems to be missing from many training regimens is the exposure to increased loading that substantially increases muscle strength. This is especially true for the muscles crossing the elbow, which (as mentioned several times) are imperative for protecting the UCL. Many pitchers never expose these muscles to increased loading. They limit the training of the elbow muscles to what they can do with a regulation baseball.

Even if a pitcher is slowly ramping up work with a regulation baseball from minimal effort to maximal effort, he or she is still limited by the baseball's weight. And maximal effort in practice is much different than maximal effort in a game.

So then how does a pitcher experience increased loading of the pitching arm?

As described above, exposure to increased loading can be achieved through the responsible use of both resistance and ballistic training.

Resistance workouts and workouts with specific implements like weighted baseballs can be used to effectively train the muscles in the shoulder and elbow. This training increases the fitness of the pitching arm, increases ball velocity, and protects the arm against future injury and fatigue.

Ballistic Training Improves Pitching Mechanics

Now we have seen that both resistance and ballistic training can reduce injury and improve velocity by causing protective muscle hypertrophy.

However, ballistic training can also reduce injury risk and improve velocity in another way. Ballistic training with weighted baseballs can actually improve pitching mechanics.

In other words, weighted baseballs can act as pitching coaches. Using them can promote more efficient mechanics that generate higher velocities and lesser loads on the more vulnerable tissues of the shoulder and elbow.

How do weighted baseballs accomplish this incredible feat?

Among other benefits, throwing an underweight baseball trains arm speed. Throwing an overweight baseball encourages more robust movement patterns and muscle activation strategies.

When throwing an underweight baseball, the arm is generally able to move faster than it can with a regulation baseball. This gives the brain an opportunity to learn the feeling of greater arm speed and the muscle fibers a chance to experience a new stimulus at a greater rate.

When throwing an overweight baseball, extraneous movements that detract from velocity in the direction of home plate are felt more easily by the body. For example, extraneous arm movement in the direction of the pitching arm side can cause more valgus stress on the elbow. Valgus stress leads to UCL injury. Use of an overweight baseball allows a pitcher to more naturally feel and correct a mechanical inefficiency like this.

In general, as the implement gets heavier, it gets harder to throw it with inefficient mechanics. This forces the brain and body to adapt.

Additionally, throwing an overweight baseball at a good velocity generally requires greater intent, or muscle activation, than a regulation baseball. Thus, overweight training encourages muscles to activate at a higher level. Teaching greater muscle activation in a practice environment is otherwise very difficult to do.

Furthermore, because weighted baseballs are like foreign objects to a pitcher who has never thrown them before, their use allows the removal of preexisting psychological inhibition.

Pitchers who have been pitching in the same inefficient manner for 20+ years often revert to bad habits as soon as they pick up a baseball of regulation weight. Changing the weight of the ball changes the psychological stimulus and therefore frees the athlete to explore uncharted and very possibly more efficient biomechanical territory.

Allowing a pitcher to feel more efficient pitching mechanics is immeasurably more effective than purely visual or verbal instruction alone. Ballistic training, along with well-designed drills and equipment, will get the best movement patterns out of an athlete when combined with solid coaching, deep analysis (with high-speed video), and appropriate cueing.

Think about learning to ride a bike. You can't really be told how to do it. You just need to learn the feeling of moving forward while balancing on only two wheels.

So, in this way, ballistic training is like taking the training wheels off the bike. At some point, you just have to do it if you truly want to learn.

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Chapter Four

A Quick Wrap Up

What did we just cover?

To understand what causes injury, it is important to understand that there is a continuum of responses biological tissue exhibits in response to applied stress.

- Less than normal stress causes tissue atrophy.
- Normal stress promotes tissue maintenance.
- More than normal stress causes tissue hypertrophy.
- Much more than normal stress causes tissue injury.

Therefore, three primary factors contribute to a pitcher's risk for injury.

1. The fitness of the biological tissue
2. The mechanics through which force is applied to and distributed to the tissue
3. The anatomy of the body

How do weighted balls help?

Resistance training and ballistic training with weighted implements both improve muscle tissue fitness by the following mechanisms.

- Muscle endurance is improved by gradually increasing the duration of time over which it is used.
- Muscle strength is improved by progressively increasing the level of loading it is exposed to.

To prevent shoulder and elbow injuries in particular, it is especially important to improve tissue fitness at these vulnerable joints.

Additionally, both resistance training and ballistic training with weighted implements significantly improve velocity.

Furthermore, ballistic training helps promote more efficient mechanics that maximize velocity and minimize dangerous joint loading.

Here's where we are going.

Over the past few decades, the baseball world has begun to discover general strategies for reducing injury risk and increasing velocity. For example, the widespread implementation of shoulder training programs seems to be slowly curbing severe shoulder injuries.

However, there is still so much more to learn.

While we know that shoulder and elbow muscles broadly protect the more vulnerable joint tissues, it remains unclear how force is specifically distributed among all joint structures during pitching.

We don't really know how much force is specifically felt by the UCL during each pitch. We also don't really know how much force is absorbed by the bones and muscles... although we do know that it is a very substantial amount.

Understanding the exact contributions of individual muscles in individual pitchers will allow for targeted interventions that act more quickly and effectively.

And while we know that tendons and ligaments do adapt to increased stress, the exact time course of the adaptation for elbow ligaments to pitching remains unknown.

The knowledge of the time course of UCL adaptation during throwing and training could immensely improve the preciseness of prehab and rehab protocols. We could know exactly how much time each pitcher needs to fully recover from Tommy John surgery. Furthermore, we could better understand the probability of success for non-surgical treatment strategies in cases of partial UCL tears.

By keeping an open mind and continuing to research, test, and re-test, we will continue to further our knowledge and make impactful advances.

Armed with an understanding of how to train pitchers the right way, with a process that encourages incremental improvement and underlying fitness, we can start to bridge the gap between what we know works and what is possible.