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Anticipated Effect of the Implementation of a Pitch Clock on Ulnar Collateral Ligament Injuries in Major League Baseball

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1. Introduction

In 2023, Major League Baseball will implement a pitch clock, allowing pitchers 15 seconds between pitches when the bases are empty and 20 seconds with runners on base.

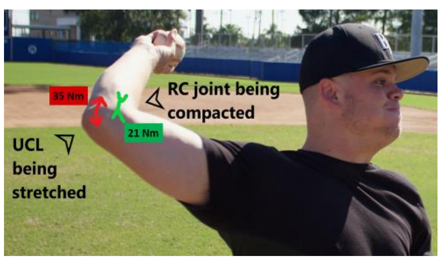
According to Tom Verducci's September 8, 2022 Sports Illustrated article, this rule change will force roughly half of all pitchers to work faster than they currently do, leaving them less time to recover between pitches and requiring them to throw more pitches in a shorter time span.

This begs the question, will the institution of the pitch clock increase the rate of UCL tears to MLB pitchers? Verducci reported that based on its figures from the 2022 minor league baseball season during which MiLB pitchers threw under similar pitch clock constraints, MLB believes the answer is "no."

Unfortunately, without proper intervention, the scientific literature suggests otherwise. Through six questions, this white paper examines why requiring pitchers to throw with less time between pitches will likely increase the number of UCL tears, and cites what actions pitchers can take to mitigate this risk.

2. Why throwing causes UCL tears

At maximum external rotation (MER) or layback, the elbow encounters external valgus torque. This external valgus torque imparts a compressive force on the lateral side of the elbow at the radial humeral joint and a tensile force across both the UCL and several muscle-tendon units (MTUs) overlaying the medial side of the elbow (A163).



While pitchers experience differences in the peak torque placed on their elbows attributable to throwing mechanics and anthropometry, the amount of peak elbow valgus torque in Newton meters (Nm) a pitcher experiences at MER is roughly equivalent to ball velocity in mph. In numerical terms, this means that if a pitcher throws a fastball at 90-100 mph, the pitcher likely experiences between 90-110 Nm of torque on the medial side of his elbow (A89, 142, 143).

In high velocity throwers, peak torque placed on the elbow often exceeds the capacity of three primary structures – the UCL, a specific set of MTUs of the flexor-pronator mass, and the radial humeral joint – to dissipate that torque (A89).

Answering the question why UCLs tear can be expressed as an algebraic expression where:

A	>	B	+	C	+	D
Peak torque on the elbow (~90-110Nm)		UCL tensile limit (~34-41)		Radial humeral joint compression limit in healthy UCL (~30-36)		Tensile limit of MTUs crossing medial elbow (?)

While "A" (peak torque on the elbow) and "D" (the tensile limit of MTUs crossing medial elbow) are variable, research has identified that "B" (the UCL tensile limit) and "C" (the radial humeral joint compression limit in an elbow with a healthy UCL) are largely fixed.

As for "B," the anterior bundle of the UCL is the primary stabilizer in resisting the valgus torque that throwing places on the elbow. According to Drs. Chris Ahmad, Medical Director for the Yankees, and Neal ElAttrache, Medical Director for the Dodgers, the ultimate torque resistance, or tensile limit, of the anterior bundle of the UCL in an intact elbow ("B") is 34 +/-6.9 Nm (A99).

As for "C," the radial humeral joint is a structural stabilizer that can resist elbow valgus torque. The magnitude of contribution depends on the amount of compression force and the magnitude of the externally applied torque. At 90° flexion, which roughly equates to the position of the elbow at MER, the radial humeral joint compression limit ("C") in an intact UCL is 33% of peak torque or 30-40 Nm (A78).

Assuming an average peak torque ("A") of 100 Nm, an upper UCL tensile limit ("B") of 41Nm, and a radial humeral joint compression limit ("C") of 33 Nm, the MTUs which cross the medial elbow must provide at least 34 Nm of varus resistance to prevent a UCL tear.

In summary, while the etiology of any individual tear is likely multi-factorial, according to literature there is always a common denominator: torque exceeded the total force limit of the UCL and supporting structures.

3. Are most UCL tears the result of a single pitch or an accumulation of pitches

Because pitchers who have torn their UCL can often point to a single pitch when they felt pain or even a pop, many view a UCL tear as an acute event. However, the literature paints a different picture. Over the course of a career, the elbow of a high-level player endures repetitive near failure stress that may cause UCL microtrauma, micro-instability, and eventually complete failure of UCL (A9). Whenever valgus forces generated by pitchers exceed the tensile strength of the UCL, microscopic tears result that may ultimately lead to ligament attenuation or tears (A8).

Case in point: in their 2016 study that examined the role of velocity in predicting UCL reconstruction amongst MLB pitchers from 2007-2015, Drs. Peter Chalmers, Brandon Erickson, Anthony A. Romeo, and Nikhil Verma excluded all pitch data beyond the 2012 season. Their stated reason:

> "…based on the current understanding of the pathophysiology of UCL injuries as the chronic accumulation of microtrauma…pitches within the 2013, 2014, and 2015 seasons potentially contribute to injuries that may not yet have undergone UCLR. These injuries would then be missed via a lead-time bias" (A61).

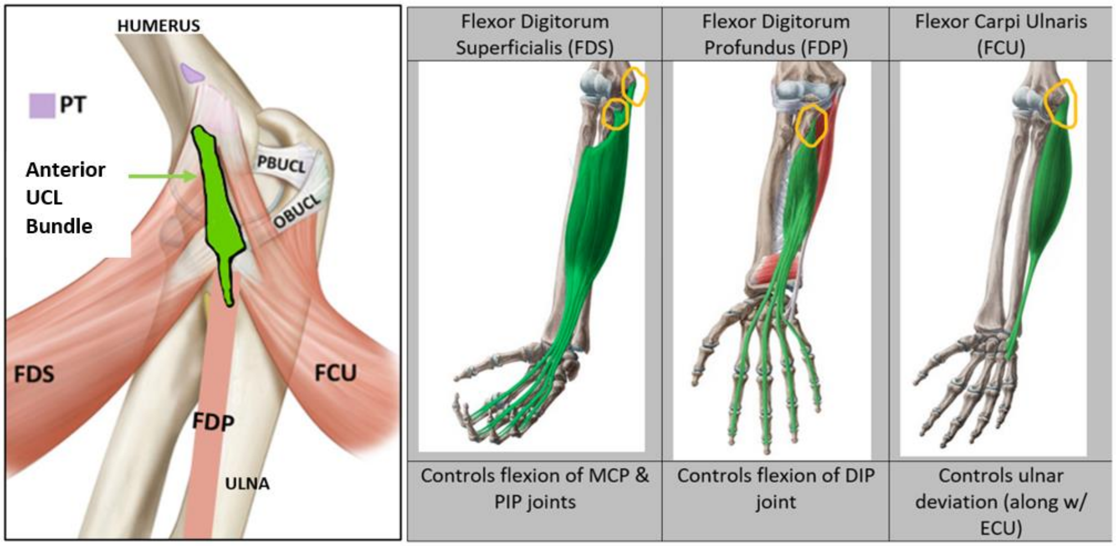
Given that the rate of UCL tears across MiLB fell 26% in 2022 despite the use of a pitch clock, it is understandable why MLB believes that the pitch clock rules it plans to implement in 2023 will not increase the rate of UCL tears. However, this belief suggests that MLB may have failed to take into consideration a reality that clinicians have long since identified. It is the cumulative microtrauma of repetitive near failure tensile stress that leads to most UCL failure, not a single pitch (A33), or for that matter, a single season.

4. **Does fatigue play a role in UCL tears**

According to Dr. Anthony Romeo of the White Sox, muscle fatigue leaves the UCL unprotected during throwing and subjects it to forces that can cause it to tear (A43). The logic flow:

1) High velocity throwing places roughly 2.5 to 3 times the amount of peak torque on the elbow than the UCL alone can handle (A89, 142, 143).
2) Three structures must work together to dissipate this torque to prevent a UCL tear: the UCL, the radial humeral joint, and the MTUs overlaying the UCL (A89).
3) The tensile limit of the UCL and the radial humeral joint compression limit in an elbow with a healthy UCL are largely fixed.
4) The only variable that can be modified to increase the amount of torque the elbow can safely withstand are the muscle-tendon units (MTUs) optimally positioned to protect the UCL, which physicians agree are the Flexor Digitorum Superficialis (FDS), Flexor Carpi Ulnaris (FCU), and Flexor Digitorum Profundus (FDP) (A2, 18, 64). (See footprint in Exhibit below).

Illustration of UCL, FDS, FCU, and FDP footprint (A5)



5) MTUs reduce the amount of strain placed on ligaments based on their level of stiffness (A96).
6) As muscles fatigue, they become 16-21% less stiff (A148).
7) Thus, in the case of the UCL, as the three MTUs best positioned to protect the UCL fatigue, they become less stiff (A18, 64, 103) and their contribution to dissipating the torque throwing places on the elbow drops. The result: strain on the UCL increases that may ultimately lead to a tear (A2, 95, 103).

This precise fact pattern led Dr. James Andrews to conclude that pitchers who regularly throw while fatigued have a 36 times greater risk of arm injury (A19).

5. Does throwing cause fatigue

Given that fatigue of the MTUs optimally positioned to protect the UCL increases the risk of a UCL tear, several researchers have studied whether high intensity throwing causes fatigue of these same MTUs.

In 2016, when MLB first floated the idea of a pitch clock, Sonne, PhD and Keir, PhD examined how fatigue accumulated during baseball games in the 2014 Arizona Fall League and how different pace of play initiatives may influence fatigue (A170). Their model predicted that forcing pitchers to adhere to MLB's contemplated pitch clock rules would elevate levels of fatigue in the MTUs most responsible for providing elbow stability, which in turn would reduce their contribution to elbow joint rotational stiffness, increase strain on the UCL, and increase injury risk.

In 2021, a team of researchers studied the impact of repetitive high velocity throwing on the medial elbow and the elasticity of the forearm's flexor-pronator muscles after having 26 college pitchers perform 7 sets of 15 max effort pitches. On average, after 60 pitches, a significant increase in the medial elbow joint space (i.e., gapping) occurred as a result of fatigue and decreased elasticity of the FDS and FCU (A159).

Also in 2021, a different research team (A156) investigated the changes in medial elbow joint space, the elasticity of the UCL, and the elasticity of the MTUs optimally positioned to protect the UCL by having 30 HS pitchers throw 100 max effort pitches in 20 pitch blocks. Their findings:

1. UCL strain increased by 12% over baseline after just 20 pitches, by 14% after 40 pitches, by 16% after 60 pitches, by 18% after 80 pitches, and by 26% after 100 pitches.
2. Muscle-tendon unit strain in the flexor-pronator mass increased by 16% over baseline after just 20 pitches, stayed flat at 40 and 60 pitches, then increased by 23% after 80 pitches.
3. Medial elbow joint space gapping increased by roughly 4% for every 20 pitches (3% after 20, 8% after 40, 12% after 60, 15% after 80, and 19% after 100).

6. As fatigue increases, what physiological changes occur at the elbow and do these physiological changes increase the chance of a UCL tear

Summarizing the two 2021 studies discussed in the prior section, as fatigue increases, the muscles that overlay the UCL will be stretched, leading to increased strain on the UCL and increased gapping in the medial elbow joint. In their 2018 study involving 70 pitchers in the Colorado Rockies organization, Shanley et. al., reported that the risk of a UCL injury was 6 times higher in professional baseball players with a medial elbow joint space exceeding 5.6 mm (A149).

7. What can be done to reduce the rate of fatigue – training intervention strategies to combat fatigue

According to the literature, pitchers wishing to reduce the risk of a UCL tear should seek to reduce their rate of fatigue of the MTUs optimally positioned to protect the UCL by:

1) Undertaking a preventive approach to arm care that includes monitoring for fatigue along with muscle testing to determine imbalances or weaknesses (A43).
2) Engaging in conditioning and strengthening exercises with special emphasis on the muscles optimally positioned to provide medial elbow support (i.e., FCU, FDS, and FDP) to delay the onset of muscular fatigue (A18).
3) Strengthening the muscles surrounding the UCL (i.e., FDS, FCU, FDP) for injury prevention (A5).

The FlexPro Grip device has been designed to optimally target, strengthen, and increase the endurance of the FDS, FCU, and FDP, the three 3 MTUs physicians agree are best positioned to protect the UCL.

The FPG Endurance Training protocol closely mirrors the protocol researchers have found can reduce muscle fatigue by an average of 28% in as little as 4-6 weeks (A100). Consider the results of the following non-peer reviewed trial.

In October 2021, the endurance levels of 30 MiLB pitchers were tested on the FlexPro Grip device. To administer this test, we familiarized all players with the device by having them perform a series of warmup exercises where they were instructed to first apply 25% of their maximum perceived effort, then 50% of their maximum perceived effort. They then were instructed to ramp up their application of force as fast as possible to 100% of their maximum voluntary contraction (MVC) and hold this force for 4 seconds. Players performed 24 total repetitions across 4 sets of 6, with 5 seconds of rest between each repetition and 15 seconds between each set. Their peak force at 4 seconds after each repetition was recorded. Players were encouraged to apply maximum effort on every repetition, receiving both verbal and visual feedback regarding each rep/set performed.

After a day of rest, players then began a 4 week Strength Training protocol where they trained 2 or 3 times per week. The protocol required the players to perform 5 repetitions of 5 exercises in 3 day cycles. Day 1 of the training protocol targeted the FDP by requiring the players to perform <u>fingertip</u> <u>flexion</u> of all 4 fingers, then the index, middle, ring, and little fingers, in that order. Day 2 of the training protocol aimed to protect against flexion to extension imbalance by requiring the players to perform fingertip <u>extension</u> of all 4 fingers, then the index, middle, ring, and little fingers, in that order. Day 3 of the training protocol targeted the FDS by requiring the players to perform <u>mid-finger</u> <u>flexion</u> of all 4 fingers, then the index, middle, ring, and little fingers, in that order.

After 4 weeks of training, the Endurance Test was re-administered. Throughout their test, players were again encouraged to apply maximum effort on every repetition and received both verbal and visual feedback regarding each rep/set.

Endurance was measured as the change in the greatest amount of force applied in the first set to the lowest amount of force applied in the fourth set.

1) The average rate of decline in force output in the initial baseline test was 33% across all 30 players tested.
2) The average rate of decline in force output for all 30 players after four (4) weeks of performing the Strength Training Protocol was 20%, indicating a 19% increase in endurance.
3) However, after excluding the eight (8) players who threw live in a game or a max effort bullpen within 48 hours of their re-test, the average rate of decline in force output for the remaining 22 players was 12%, indicating a 31% increase, roughly matching the results of the peer-reviewed study upon which we based our Endurance training protocol.

Note: these results were achieved following 4 weeks of FPG's Strength Training protocol. There is reason to believe results may be improved following 4 weeks of the Endurance Training protocol, which was specifically designed to reduce fatigue.

8. Summary

MLB's implementation of a pitch clock in 2023 will undoubtedly cause a significant percentage of MLB pitchers to throw while experiencing increased levels of muscle fatigue in the MTUs best positioned to offload torque on their UCL. Consequently, absent specific training interventions designed to increase their endurance level of these key MTUs, their risk of a UCL tear will increase. The scientific literature is unequivocal.

1) UCLs tear whenever torque placed on the elbow exceeds the capacity of 3 primary structures: the UCL, the radial humeral joint, and the MTUs crossing the medial elbow.
2) Most tears are the result of repetitive near failure stress that causes UCL microtrauma and eventually complete failure of UCL.
3) Fatigue in any of the MTUs best positioned to protect the UCL results in a greater amount of torque being placed on the UCL.
4) High velocity throwing causes fatigue in these MTUs, which causes the amount of torque placed on the UCL to routinely approach a breaking point.

Players wishing to reduce their risk of a UCL tear should seek to reduce their rate of fatigue of the MTUs best positioned to offload torque on their UCL. Initial testing has proven FlexPro Grip can do precisely that in a way that no other training methodology can.

Note: while beyond the scope of this paper, FPG's Readiness Test enables players to routinely monitor for fatigue in these same MTUs through its Readiness testing.

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