Loss in Movement as the Game Progresses

by Noah Woodward

The story is among the classics in baseball history. The major players were Pedro Martinez, Grady Little and some numbers. It was the seventh game of the 2003 American League Championship Series, and Martinez was about to make his third trip through the Yankees lineup even though he had thrown 115 pitches. When Little asked, Martinez insisted he was fine. The situation suggested he wasn't.

Martinez had a great 2003 season. He came in third in American League Cy Young Award voting after he posted a 2.22 ERA (the lowest in the majors) and a 1.04 walks and hits per inning pitched, or WHIP (second-lowest). Martinez actually managed to strike out more hitters in fewer innings than his competitor in the Cy Young race, Roy Halladay.

On the other hand, Halladay posted a 22-7 record that year, and it's probably that simple fact that propelled him to the top of the Cy Young voting. Martinez's 14-4 record surely cost him, though it understated his contributions to the Red Sox that season.

The accumulation of wins is a fickle pursuit, but one thing a pitcher can do to maximize his chances of picking up a win is to simply stick around. Good pitchers who are able to pitch deep into the later innings of games are more likely to receive run support, at the same time keeping the ball out of the hands of less-skilled middle relievers. Halladay, for instance, was a horse in 2003. He averaged about seven and a third innings per start, and completed nine games all by himself.

Martinez, on the other hand, averaged somewhere around six and a third innings per start, and threw just three complete games. Martinez pitched no more than seven innings in all but five of his 29 starts. You can think of him as a decade-old version of Stephen Strasburg, but with a perfectly healthy elbow and a little more attitude.

So why exactly was Martinez so limited in his usage? The most convincing evidence comes in a troubling pattern that he exhibited that season. Martinez was untouchable from pitches one through 25 in his 2003 starts, with a ridiculous 9.33 strikeout-to-walk (K/BB) ratio, allowing just two home runs in 181 plate appearances. From the next pitch on, however, everything seemed to go downhill. If we look at opponent on-base plus slugging percentage (OPS) in terms of 25-five pitch intervals, here is what we see from him:

- Pitches 1-25: .498
- Pitches 26-50: .589
- Pitches 51-75: .588
- Pitches 76-100: .644
- Pitches 101+: .706

Most pitchers' performances decline during a game, just like Pedro Martinez's. This past season in the majors, batters had a .700 OPS against starting pitchers the first time through the lineup; this statistic jumped to .730 the second time through. How about the third? .760. Strikeout rates, walk rates, and extra-base hit rates appear to correlate pretty well with times through the order, too. Roster limitations aside, we understand that the ideal workload for most pitchers is less than a dozen batters per game.

Familiarity is probably one reason for the within-game decline. As batters become more familiar with the pitcher's stuff and approach, they adjust during the game, learn to lay off certain pitches and better time their swings.

But how much within-game performance loss is due to familiarity, and how much is in fact due to fatigue? This is nearly impossible to answer, because you can't have within-game familiarity without fatigue. That is, you can't have a hitter face a pitcher multiple times in a game without that pitcher first tiring himself out by facing other hitters along the way. Because of the way the game is played, a pitcher usually throws at least 30 pitches before facing the same hitter twice.

For this reason, traditional and sabermetric measures of success, dependent on pitch count, are influenced by both familiarity and fatigue. Runs allowed, strikeouts per nine innings, and even swinging strike rates are influenced by the quality of the pitch thrown, and the knowledge that a hitter gains from previous at-bats in the same game.

If we want to try to isolate the impact that fatigue has on effectiveness, then we have to focus solely on pitch quality. For the purposes of this study, I will define pitch quality, or "stuff'," as the combination of speed and movement of a fastball. A starter who possesses a fastball with both of these qualities misses more bats than the average starter, and also prevents more runs with the pitch.

Let's not take this assertion as fact. In order to evaluate the connection between positive performance, velocity and movement, we need data on each of these three things. Fortunately, we have PITCHf/x for that.

We're entering an era in which all major league ballparks are going to have cameras pointed at anything that moves on the field. In fact, this era has already begun. Sportvision's PITCHf/x system has allowed us to (roughly) classify pitch types, speeds, locations, etc. The technology isn't perfect, but it has given us something to get excited about over the past few years. One useful bit of information that PITCHf/x

provides is pitch spin deflection values, which help us estimate pitch movement. In this article, I'm going to consider how these vary with production and fatigue.

Before I go any further, I want to bring up concerns that others have regarding the use of spin deflection estimates provided by PITCHf/x. One thing I should make clear is that spin deflection is measured as the horizontal and vertical deviation from a straight-line path, and *not* actual pitch movement. Spin deflection values also do not incorporate outside forces like gravity and drag. While spin deflection is not exactly the same thing as movement, it does act as a valuable proxy for it.

Look at the charts below. The data behind these graphs include over 1.5 million fastballs thrown by starting pitchers from 2010-2013. FanGraphs calculates the run value of every pitch by looking at one of two things:

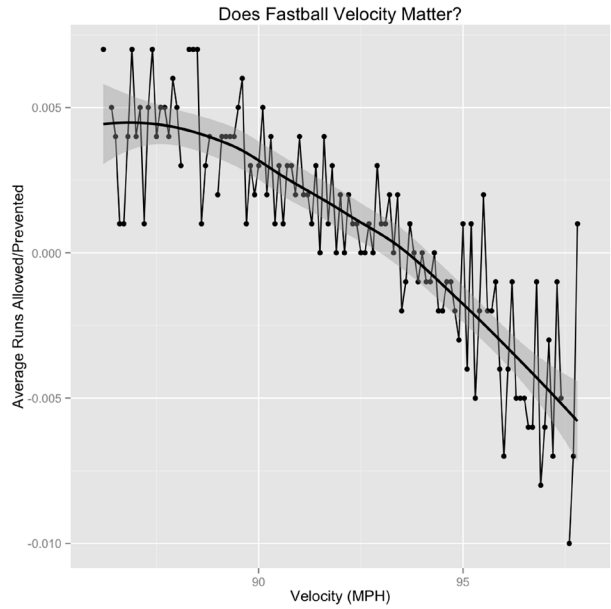
- If the ball is put in play, the run value of the outcome.
- If the ball isn't put into play, the run value of the change in count.

Run values are expressed as "linear weights," in which the average run value is set at zero. In 2003, for instance, the average run value of a single was 0.45 runs, while the average run value of a strike on a 1-1 count was -0.08 runs (that's a negative number). Any difference in the pitcher's favor is a negative, while any difference in the batter's favor is positive.

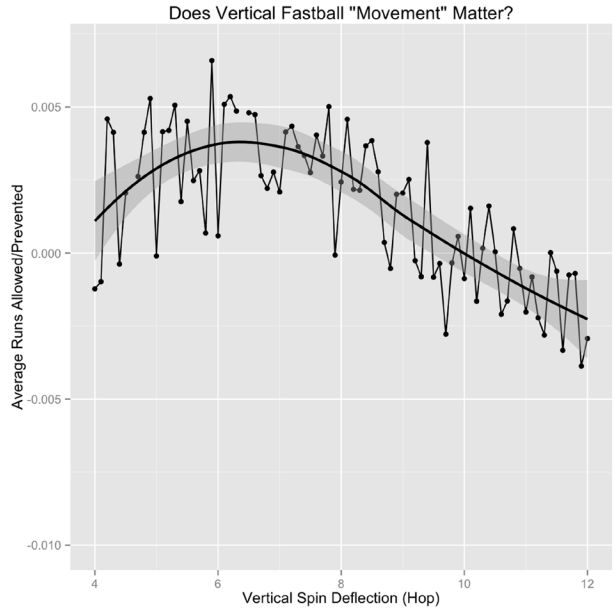
The process for assigning run value to a ball or strike was pioneered by Hardball Times writers Josh Kalk and John Walsh (as well as FanGraphs' Dave Allen) several years ago. It is determined by analyzing the difference, in our example, of the final outcome of all plate appearances that have a 1-1 count and the final outcome of all plate appearances that have a 1-2 count. The difference is the run value of the ball.

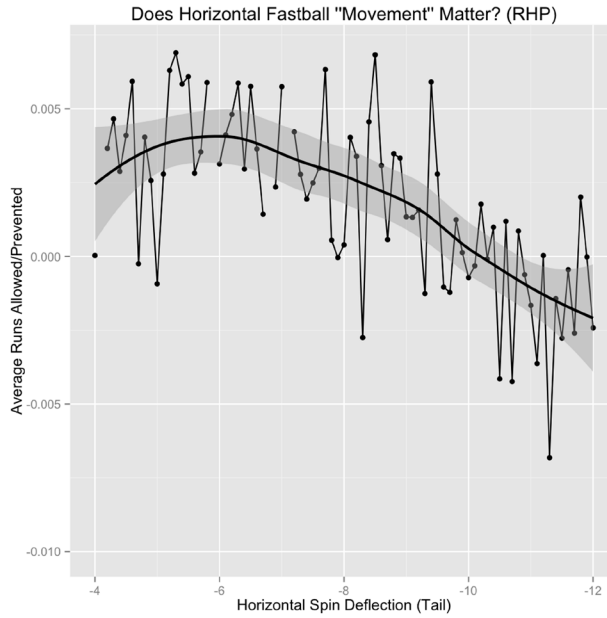
You'll find a similar approach elsewhere in this *Annual* in Jon Roegele's article about the strike zone.

Anyway, each graph depicts the relative effectiveness (in terms of runs allowed or prevented per pitch thrown) of the pitch characteristics that I described above. In the first, we see that velocity is strongly related to run prevention. As the velocity of a fastball increases, the run values go down—meaning that the pitch results in fewer runs scored.



We see similar trends in the next two graphs, which depict vertical and horizontal spin deflection. As the graphs show, the more deflection on a pitch, the fewer runs allowed, on average.





With one caveat, pitchers allow fewer runs on pitches with more spin deflection. In fact, a two-inch increase in horizontal (or vertical spin) appears to have roughly the same effect on results as a two-mile per hour increase in velocity. True, we can't look at these results in a vacuum—but it is clear that spin deflection matters.

What is our one caveat? Both types of spin interact with each other and with velocity, and this interaction explains the peaks we see in the spin graphs above. Adding more vertical spin deflection to pitches that already have three to six inches of it appears to produce worse outcomes for pitchers, but remember that these pitches often have larger horizontal spin components (think two-seam fastballs and sinkers).

Now that I have examined the relevance of velocity and spin deflection, I want to look at how these fastball characteristics are affected by fatigue.

Fastball velocity, as it relates to fatigue, has been fairly well researched. In 2011, Jeremy Greenhouse of Baseball Prospectus came out with a study suggesting that velocity peaks around pitch 20 and steadily declines throughout the rest of a start. That's why it makes sense that flamethrowers like Aroldis Chapman often face pitch count limits of 20-30 pitches in an outing, because this type of reliever relies heavily on velocity and (not much else) to be successful.

While Greenhouse looked at only a pitcher's fastest 25 percent of all fastballs thrown, my sample of all fastballs thrown suggested that fastball velocity peaks a little earlier than 20 pitches. I also found that velocity then declines from this peak for about 10 to 15 additional pitches before flattening out for the rest of a start. It is worth noting, however, that while fatigue clearly drives velocity downward, some

pitchers also demonstrate the ability to increase velocity in tough situations. You can read more on that finding by checking out Roegele's recent work for Beyond the Box Score.

While the average major league pitcher loses velocity as the game progresses, almost one in four gains at least a little bit of velocity while throwing more pitches. Who are these pitchers, and what makes them so special? Justin Verlander throws hard, and it turns out he gains more velocity per pitch than any other starter in the game. I'll have more on him later. The rest of these pitchers aren't exactly soft-tossers, either. Derek Holland, Max Scherzer and Edwin Jackson all have league-leading fastballs in terms of velocity, and all three post at least modest gains as they pitch in a game.

However, the majors' three hardest throwers, Matt Harvey, Stephen Strasburg and Jose Fernandez, all are in-game velocity losers. By and large, the sweet spot for those who gain velocity is a baseline fastball in the 90-93 mph range.

So what about the other component that helps make up "stuff"—movement? I'm not sure how anyone—commentators, pitching coaches or even scouts—can determine when a pitcher has lost an inch or two of movement. It definitely makes sense that fastballs flatten out as a pitcher fatigues, but really, how do we actually know that this happens?

In attempting to answer this question, I examined the relationship between spin deflection values and pitch count—which serves as a measurable indicator of fatigue. This technique required grouping and averaging of thousands of fastball spin deflection values according to pitch count level and creating unique regression "slopes" (or trend lines) for each pitcher in my sample. Positive slopes indicate that a pitcher gains fastball movement throughout a start, and negative slopes indicate the opposite. Composite slopes combine horizontal and vertical components.

The chart below depicts the number of starting pitchers who experience horizontal, vertical and composite movement gains and losses as a result of fatigue. So, for example, 74 starting pitchers lose horizontal movement as they throw more pitches. The information presented provides mixed support for what I'm sure most of us thought to be true: Most starting pitchers lose fastball "hop" as they fatigue, and most also lose overall spin deflection. However, the same cannot be said for horizontal spin.

Component	Losers	Gainers	% Losers
Horizontal Spin	74	71	51.0%
Vertical Spin	115	30	79.3%
Composite Spin	111	34	76.5%
Velocity	109	36	75.2%

This table isn't enough to help us conclude that fatigue weakens movement. We need to keep in mind that a pitcher who loses spin deflection in one dimension might be gaining it in another, and this exchange might actually benefit that pitcher.

For example, spin deflection readings for starters who throw two-seam fastballs are tricky to interpret. It makes sense that pitchers would gain horizontal movement at the expense of vertical movement, so a loss in vertical movement can be associated with better results for this type of pitch. These pitchers should not be confused with another more concerning group—the composite spin deflection losers. These pitchers lose both horizontal and vertical movement as a result of fatigue.

Below, I'll discuss a few pitchers who lose in terms of spin deflection and velocity. I'll make connections between these trends on overall performance when possible, and then do the same for those who notably resist the effects of fatigue on fastball effectiveness.

The Losers

Jake Westbrook

This 36-year-old starter suffers from major fatigue issues. It isn't tough to spot the impact that his lack of fastball endurance has on his performance. Westbrook is not a bad starter for the first few innings of a game, but he is an awful one in the middle and late innings as his pitch count rises. His K/BB ratio plummets from around 1.18 to .40 after his 75th pitch, while his OPS-against jumps from .734 to .912. Westbrook's fastball velocity declines about 2.3 mph per 100 pitches, and the horizontal spin deflection he gets on it declines by about an inch per hundred. For a pitcher who relies on sinker-type movement, these trends are troubling.

Jason Marquis

Marquis loses 1.6 inches of horizontal movement and 2.1 mph off his sinker per one hundred pitches. For Marquis, the raw results don't reflect the decline he sees in sinker effectiveness. This may be because he cuts his sinker usage from about 64 percent at the start of a game down to about 51 percent by the 50th pitch. Marquis knows that his sinker is not a plus offering by the fifth inning of a start, and he began to rely heavily on his slider last year to compensate.

Roy Halladay

Remember him? It has been 10 years since he won that Cy Young in 2003. We can only speculate as to the impact of wear and tear on Halladay's in-game endurance, but it is clear that he now becomes less effective as he throws more pitches. Halladay loses horizontal movement on his sinker and on his cutter at a rate that is greater than all other qualified starters except Marquis. He also lost, on average, .76 miles per hour per start over that span. Halladay's declining within-game fastball usage

mirrored its change in quality pretty well over the past two years, and his off-speed pitches kept him afloat until he broke down in 2013.

Travis Wood

Last year, high pitch counts really were a problem for the Chicago left-handed starter. While he performed much better than the league-average pitcher his first two trips through a lineup, he tended to collapse if Cubs manager Dale Sveum leaned on him for any more than that. From pitches 1-75 in 2013, Wood's OPS-against was .586. From pitch 76 on, his OPS-against rose by 231 points to .816. Wood was essentially this past year's Pedro Martinez.

Wood throws three different types of fastballs. On the whole, he loses about 1.2" of horizontal fastball deflection for each 100 pitches thrown, while also losing 1.2 mph per fastball over that same span. These amounts may not seem large, but they both rank in the top 25 percent of all starting pitchers. Finally, Wood's vertical spin deflection decreases ever so slightly as he fatigues. Because Wood loses in terms of composite movement and in terms of velocity, we can argue with confidence that he loses "stuff" as his pitch count rises.

The Gainers

Justin Verlander

We all know that basic human limitations don't really apply when it comes to Verlander. Detroit's ace gained an average of 1.96 mph per 100 pitches thrown from 2012-2013, and he leads in this category by a large margin.

He struck out almost 27 percent of all batters he faced last year after the 100-pitch mark, and he allowed a total of seven extra-base hits in 109 plate appearances. The righty is able to gain a modest 0.28 inches of horizontal movement per 100 pitches on his fastball, and he does this without sacrificing any vertical hop.

Chris Tillman

Tillman's strikeout rate and walk rate improved as he made his trips through opposing lineups last year. In doing so, he won over Orioles fans while establishing himself as the team's most dependable starter. Tillman is a velocity gainer, adding about 0.8 mph per 100 pitches to a plus offering. But Tillman is also unique in that he doesn't lose horizontal movement while steadily gaining velocity throughout the course of a start.

Jorge De La Rosa

In 2013, left-hander De La Rosa gained an average of 0.91 inches in horizontal spin deflection per 100 pitches, arguably the highest in-game lateral spin increase for any qualified starter throwing a sinking fastball. He is a surprising leader in this category, but the results back up his constantly improving fastball quality.

Unlike many other horizontal-spin gainers, De La Rosa doesn't lose velocity. In fact, he gains almost a full mile per hour per 100 pitches thrown. His strikeout numbers also remain stable as his pitch counts mount. In pitches one through 50, De La Rosa struck out around 14 percent of all batters he faced. His strikeout rate for any pitch after that point was about 13 percent. Tommy John surgery looks to have created the perfect example of anti-fatigue in De La Rosa.

Other Tommy John Survivors

De La Rosa's strong recovery and resistance to fatigue motivated me to take a closer look at other starters who pitched in 2012 or 2013 with fresh ulnar collateral ligaments in their elbows. Westbrook, Strasburg, John Lackey and Adam Wainwright are some of the most recent pitchers to go through this process and live to pitch in either 2012 or 2013. We already know that Westbrook doesn't handle fatigue well, but let's see if the others held up better.

They didn't. All three saw moderate-to-severe declining fastball velocities by pitch count in 2012-2013. Lackey leads all starters with almost three mph lost from his first pitch to his 100th. Wainwright and Strasburg lost 1.3 and 0.73 mph per 100 pitches respectively. Lackey was able to gain in terms of horizontal spin, but all were losers in every other category. These five pitchers obviously don't tell all in terms of Tommy John surgery as it relates to pitcher fatigue, but this group warrants its own study.

Conclusions

I've attempted to prove two things. First, fastballs with less hop, tail, bite, or hair (if you're a Dennis Eckersley fan) are less effective than other fastballs. Second, for a majority of starting pitchers, fatigue does have an adverse effect on spin deflection. While we don't have PITCHf/x data on Pedro Martinez in 2003, the data that we do have today suggest that fatigue has a clear effect on overall fastball effectiveness.

Now that we have explored the general trends that professional pitchers exhibit, more work needs to be done on the basis of the individual pitcher level. Each pitcher is unique, and as we have just seen, all react differently to the rhythm of the game and to the burden of throwing 100 pitches in a start.

For some, the data provide useful bits of information that may or may not have practical implications. For example, Jon Lester's fastball is at its best the first time he throws it, and the next 10 or so he throws after that also have exceptional movement and velocity. However, he also experiences a constant dramatic decline in fastball "stuff" until he throws his 30th pitch or so.

Pitch count data will allow us to examine fatigue in a way that has never been done before. The opportunity to relate patterns in pitch effectiveness and pitcher release point to fatigue already allows teams to make effective usage decisions that minimize arm injury risk. The height of a pitcher's elbow at release is commonly

associated with fatigue, and may also be linked to ligament tears. Soon enough, the fan will be able to monitor these critical points of fatigue from home.

References

- Jeremy Greenhouse, Baseball Prospectus, "Spitballing: Fourth Time's the Harm" (*baseballprospectus.com/article.php?articleid=13117*)
- Jon Roegele, Beyond the Box Score, "How and When Does Velocity Change During a Start?" (*beyondtheboxscore.com/2013/5/16/4334912/how-when-does-velocity-change-during-start-game-pitchfx-sabermetrics*)