By the Numbers

Volume 26, Number 1 The Newsletter of the SABR Statistical Analysis Committee March, 2016

Review

Academic Research: Baseball Surgery

Charlie Pavitt

The author reviews recent academic studies on baseball injuries – incidence and recovery – with an emphasis on Tommy John surgery.

Over the past couple of years the prestigious *American Journal of Sports Medicine* has been the primary home for a burgeoning research literature concerning professional players' response to major surgery.

Not surprisingly, most of the publications have been about pitchers and focused on the prevalence and outcomes of ulnar collateral ligament reconstruction (Tommy John) surgery. We'll start with the prevalence data.

Stan Conte (who recently resigned as head of the Dodgers' medical staff to concentrate on research) and a group of associates (2015) used a survey of both major and minor league players to determine that at the time of their data collection (2012 and 2013), 25 percent of current major league and 15 percent of current minor league pitchers had experienced the procedure. That's in contrast to only 3 percent of players at other positions.

Older pitchers were more likely to have had the procedure than younger pitchers. "Pitching position" (starter vs. reliever), handedness, and (despite some media claims) nationality had no impact on surgery prevalence. Only about 10 percent of cases reported a later bout of elbow surgery, about the same percentage as had subsequent shoulder surgery. Interestingly, although 51 percent of major leaguers and 42 percent of minor leaguers felt that they pitched slower after the surgery than before, 26 percent and 46 percent respectively believed they now threw faster.

Getting to the results of the procedure, a group of nine physicians led by Erickson (2014) contributed a carefully-done examination of its aftermath among major league players. Starting with a sample size of 179 pitchers who had experienced the procedure through 2012, the authors first reported that 148 eventually returned to the majors afterward. Of the rest, 26 returned only to the minors, and five were unable to return at all.

The mean age of surgery was at that time 28.4 years. The rate of surgery had increased significantly across the years although not at a smooth rate; there were fewer than five procedures per year most seasons before 2000, followed by an abrupt jump to above 15 per year through 2011, and ending with a bonanza of more than 30 cases in 2012.

The meat of the authors' analysis was a set of comparisons against a meticulously chosen control group matched pitcher-to-pitcher along a wide range of variables (age, body mass index, years in MLB, performance, "pitching position," and handedness). For each control, an "index year" in their career was chosen that corresponded to the year in which the matched injured pitcher's "case" (procedure) occurred.

Comparing their performance for the three years after surgery with the three years before, Tommy John survivors were lower on several indicators of activity (fewer innings per game and per season, fewer wins, losses, shutouts, and complete games), had little change in DIPS performance (strikeouts, walks, and home runs per inning), but exhibited markedly improved ERA and

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The previous issue of this publication was May, 2015 (Volume 25, Number 1).

WHIP. As the authors note, starters who convert to relievers tend to have improved stats; at least some of these changes are due to such a role change following surgery.

The control group pitched a bit less after their index year and also pitched worse after their index year in regards to homers, hits, and runs given up per inning – likely the result of normal aging.[1]

There were no substantial differences between cases and controls two seasons before the surgery. In the season immediately before, however, the cases displayed markedly less ability to pitch (fewer appearances, innings, wins, losses, complete games) and worsened performance on just about every measure included (ERA, hits per inning and DIPS measures).

The season immediately following the surgery, the players predictably continued to pitch less, but their performance was consistently better than controls. These performance advantages remained in the second year after surgery. In addition, the differences in ability to pitch largely disappeared.

Continuing on the same vein, a large group of physicians including James R. Andrews (Osbahr, Cain, Raines, Fortenbaugh, Dugas, & Andrews, 2014) examined the ten-year outcomes for 256 players, 228 of whom were pitchers, with Tommy John surgery performed by Dr. Andrews. Of the total (without separating out the position players), 19 of the 24 major leaguers undergoing the procedure were able to return to the majors, with the rest returning to the minors. Of the 88 minor-leaguers who underwent the surgery, 40 of them eventually appeared in the majors. Of the rest, 27 got back to their previous minor league level, while 11 remained at a lower level.

Major leaguers were able to return for an average of 7.5 years after surgery, minor leaguers an average of 4.2 years.

Continuing in this vein, Makhni, Lee, Morrow, Gualtieri, Gorroochum, and Ahmad (2014) analyzed a group of pitchers for re-injury after Tommy John surgery. Of 92 who appeared ten or more times in a season both before and after surgery, 63 (68.5%) had a subsequent elbow injury, as compared with 97 of 192 (51%) in a matched control group. Analysis of post-surgery performance basically replicated Erickson et al.

A couple of studies have examined "revision" surgery, that which occurs after a second injury following the "primary" injury and Tommy John procedure. Jones, Conte, Patterson, ElAttrache, and Dines (2013) uncovered 11 relievers and 7 starters who had a second instance between 1996 and 2009. 14 of these had returned to action with two seasons, but with a loss in workload (50% for the relievers and 35% for the starters as compared to beforehand). Marshall, Keller, Lynch, Bey, and Moutzouros (2015) found 33 surgeries between 1996 and 2012, and age-matched them with the same number who had never suffered the surgery. Those undergoing the procedure had relatively shorter careers postoperative (3.2 versus 4.0 years) and a smaller workload (37 versus 75 innings), but not much difference in performance in the three previous versus three subsequent seasons.

As for labrum tears, the best work on this is by Ricchetti, Weidner, Lawrence, Sennett, and Huffman (2010). These authors compared 51 pitchers receiving surgical repair between 1995 and 2004 with a control group of 110 pitchers active in 2010, the groups fairly well matched by age, experience, height, weight, handedness, and performance the three seasons prior to injury (versus 2007 through 2009 for controls), although the controls were less likely to be starters.

Eventually, 72.5 percent of the cases returned to action, but their first season back resulted in fewer innings pitched, and a half-run increase in ERA – both figures substantially worse than the control group. However, the mean performance by the cases slowly but steadily returned to their pre-injury levels over the next three years and eventually came to approximate the control group.

Cerynik, Ewald, Sastry, Amin, Liao, and Tom (2008) examined an overlapping set of 42 pitchers injured between 1998 and 2003, although with no control, and reported analogous performance detriment right after the surgery and return to previous levels in the next years.

Turning to the other half of the battery, Kilcoyne, Ebel, Bancells, Wilckens and McFarland (2015) examined the prevalence and variety of injuries serious enough to place catchers on the disabled list. They uncovered 134 cases over the 2001-2010 span, with 20 resulting from home-plate collisions and the other 114 from other causes, with no collision/not-collision difference in days on the disabled list. Leg, shoulder, and knee injuries were most prevalent (over 30), but 7 of the 15 ankle injuries came from collisions. There were 11 reported concussions, mostly by being hit by a bat or foul ball.

[1] The best data comparing the cases with the controls is not included with the article per se but was available to those with access (i.e., not the general public) at *http://ajs.sagepub.com/content/suppl/2013/12/18/0363546513510890.DC1*

As for concussions specifically, Wasserman, Abar, Shah, Wasserman, and Bazarian (2015) attempted to study the their impact on batting performance both soon after and a longer after the event. They uncovered 66 instances of players suffering concussions between 2007 and 2013 that met a series of criteria (including no multiple events in a year, no events leading to more than a month of disablement, plus cutoffs for insufficient playing time) and compared their batting to 68 players on the bereavement or paternity lists and thus missing playing time for non-health reasons. As their data set included players who did not require DL time along with those that did, many more catchers qualified (26) than in Kilcoyne et al., along with 20 outfielders, 13 corner infielders, and only 7 middle infielders.

Some of their comparisons between concussed players and the control group were confounded by differences in time missed (means of around 11 games for concussions and only five for the others). Happily, the authors sidestepped this confound in additional contrasts limited to those missing less than 10 days for (sample sizes of 38 for concussions and 65 for the others); I will quote those figures.

With no differences in the two weeks prior to injury, the two weeks after returning to action resulted in significantly worse performance for the concussed than the control (BA, .232 vs. .266; SA, .366 vs. .420; OBA, .301 vs. .320; OPS, .667 vs. .746). These figures were basically the same for the entire sample. Fortunately, the performance decrement for the concussion victims had become far smaller in the 4 to 6 week period after return.

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Pinch Running On Empty

Bill Deane

Managers make many substitution decisions in the course of baseball games, to achieve small, theoretical advantages. Do those work in practice? In this study, the author examines actual World Series game outcomes after the insertion of a pinch runner, to see if those substitutions actually improved the eventual results.

When watching baseball games, I often find myself shaking my head about what I call overmanaging. Each team sends out parades of relief pitchers, pinch-hitters, and defensive replacements, resulting three hours later in a game between each club's junior varsity squads. For example, over the past seven seasons, the American League has used an average of over 1,500 pinch hitters each year, with aggregate batting averages of .208, .206, .216, .207, .208, .208, and .215, respectively. Since pitchers rarely bat in this league, one must wonder whom these guys are hitting for which makes this such a brilliant strategy.

One thing I have often wondered about is the pinch-runner. Typically, a lumbering slugger is replaced by a speedy bench-player late in a close game. Obviously, the purpose of such a substitution is to increase a team's chances of scoring a run. So, how often does a pinch-runner score a run? More importantly, how often does he score a run which would *not* have been scored by the man he replaced? On the flip side, how often does the runner – perhaps not warmed-up enough, or being over-aggressive to justify his role – get caught stealing or otherwise retired trying to take an extra base? And how often does the replaced player's spot in the batting order come up again, with a weaker batter in his place?

Perhaps someone smarter than me could answer these questions (and ones I'm not even considering) using Retrosheet data, although there would still be a lot of guesswork involved. But no one took the bait when I brought up the subject on the SABR-L message list, so I decided to do a little back-of-the-envelope study using the Neft-Cohen book, *The World Series*, which has play-by-play of every Fall Classic from 1903 on. I checked 1970 to 1989, the last 20 years covered by my edition of the book. Acknowledging the small sample size (120 games), I found the results surprising and interesting, so I thought I'd share.

There were 71 pinch-running substitutions in those 20 years. Only 12 of the runners wound up scoring. Twelve out of 71! I tried reconstructing the innings for those dozen cases under the scenario that the runner was not replaced. I assumed he would neither have advanced nor tried to advance any more bases than the following batters (or, in two cases of shoddy defense, one base each on an erratic pickoff attempt and a passed ball).

The results? Only *one* of the twelve runs could be attributed to the baserunning prowess of the substitute.

I tried to be objective, but don't expect you to take my word for it, so here are the twelve cases.

World Series Runs Scored by Pinch Runners, 1970-1989

1971, Game 2: Baltimore's Paul Blair ran for Frank Robinson at first base in the sixth inning with none out (rather than a strategic move, this would appear to be giving Robby, a fine baserunner, the rest of the day off; the O's had a 10-0 lead at the time). Elrod Hendricks singled to left, with Blair advancing to third. Brooks Robinson singled to center, scoring Blair and sending Hendricks to second. Davey Johnson struck out. Mark Belanger grounded to Pirates' second baseman Dave Cash, who stepped on second to force Brooks, with Belanger reaching first and Hendricks moving to third. Jim Palmer grounded to first to end the inning. Conclusion: Frank Robinson would have scored, even if he had stopped at second on Hendricks's single, and at third on Brooks Robinson's, since Hendricks ultimately wound up at third base.

1972, Game 4: Oakland's Allen Lewis ran for Gonzalo Marquez at first base with one out in the ninth inning. Gene Tenace singled to left, with Lewis stopping at second. Don Mincher singled to right-center, scoring Lewis with Tenace going to third. Angel Mangual singled through the right side of a drawn-in infield to score Tenace with the winning run. Conclusion: Marquez would have scored, even if he stopped at third on Mincher's hit, since another hit followed that one (but if the lumbering Tenace could get to third, Marquez would have scored anyway).

1972, Game 7: Oakland's Allen Lewis ran for Gene Tenace at second base with two out in the sixth inning. Sal Bando doubled over Reds' center fielder Bobby Tolan's head, scoring Lewis. A walk and error followed before the final out. Conclusion: Tenace would have scored on Bando's two-bagger.

1973, Game 2: Oakland's Allen Lewis ran for Deron Johnson at second base with none out in the ninth inning. Bert Campaneris struck out. Joe Rudi grounded to third, Lewis holding second. Sal Bando walked. Reggie Jackson singled to right, scoring Lewis and sending Bando to third. Gene Tenace singled to left, scoring Bando, with Jackson stopping at second. Jesus Alou grounded out to end the inning. Conclusion: Even if he didn't score on Jackson's single, Johnson would have scored on Tenace's.

1978, Game 5: The Yankees' Paul Blair ran for Mickey Rivers at first base with two out in the seventh inning (Denny Doyle was on third). Roy White singled to right, scoring Doyle, with Blair stopping at second. Munson doubled to deep left-center, scoring Blair and White. Reggie Jackson grounded out to end the inning. Conclusion: Rivers would have scored easily on Munson's double.

1979, Game 4: The Orioles' Rick Dempsey ran for Terry Crowley at third base with one out in the eighth inning (Tim Stoddard was on first). Al Bumbry grounded to Pirates' shortstop Tim Foli, who tossed to second base to retire Stoddard on a force, with Bumbry reaching and Dempsey scoring. Kiko Garcia struck out to end the inning. Conclusion: Crowley would have scored just as Dempsey did.

1981, Game 2: The Yankees' Bobby Brown ran for Lou Piniella at first base with one out in the eighth inning. Graig Nettles dropped a single to center, with Brown stopping at second. Bob Watson singled to left, moving Nettles to second and scoring Brown. On a pickoff attempt, the Dodgers' Dave Stewart threw the ball into center field, advancing both runners a base. Rick Cerone was intentionally walked. Willie Randolph hit a sacrifice fly to deep right, scoring Nettles, before Goose Gossage fanned to end the inning. Conclusion: Even if Piniella had stopped at third on Watson's single, he would have scored on the ensuing throwing error.

1981, Game 6: The Yankees' Aurelio Rodriguez ran for Graig Nettles at first base with one out in the sixth inning. Rick Cerone and Larry Milbourne both walked, pushing Rodriguez to third. Lou Piniella singled to center, scoring Rodriguez. Two outfield line-outs followed. Conclusion: Nettles would have scored from third on Piniella's single.

1982, Game 7: The Cardinals' Mike Ramsey ran for Gene Tenace at first base with one out in the sixth inning (Ozzie Smith was on third base, Lonnie Smith on second). Keith Hernandez singled to right center, scoring both Smiths and sending Ramsey to third. George Hendrick singled to right, scoring Ramsey, with Hernandez stopping at second. Darrell Porter grounded to second, forcing Hendrick, while Porter reached and Hernandez advanced to third. Steve Braun grounded out to end the inning. Conclusion: Even if he had stopped at second on Hernandez's single, and at third on Hendrick's, Tenace would have scored on the force out.

1983, Game 4: The Phillies Bob Dernier ran for Bo Diaz at first base with one out in the ninth inning. Ivan DeJesus then grounded to third, with Dernier advancing to second; Dernier subsequently scored on Ozzie Virgil's single to center before the final out. Conclusion: It's reasonable to believe Diaz would have either been retired at second on the grounder, or held at third on the single, so credit the pinch-runner.[1]

1985, Game 6: The Royals' Onix Concepcion ran for Steve Balboni at first base with none out in the ninth inning (Jorge Orta was at second). Jim Sundberg attempted to sacrifice, but Orta was forced out at third, while Sundberg reached and Concepcion advanced to second. Both runners moved up on a passed ball by Cardinals' catcher Darrell Porter. Hal McRae was intentionally walked to load the bases. Dane Iorg singled to right, scoring both Concepcion and Sundberg with the winning runs. Conclusion: Balboni would have scored just as Concepcion did.

1986, Game 7: The Mets' Wally Backman ran for Tim Teufel at third base with one out in the sixth inning (Keith Hernandez was at first). Gary Carter reached when Red Sox right fielder Dwight Evans attempted a diving catch on his blooper; Backman scored, but Hernandez was forced out at second. Darryl Strawberry lined out to end the inning. Conclusion: Teufel would have scored just as Backman did.

It's likely I have overlooked other factors, or that seeing the plays on film rather than on paper might have resulted in a different conclusion somewhere. But the sum of my conclusions is that, of those twelve, there was only one instance in which it could reasonably be argued that the player he replaced would not have scored: the 1983 tally by Bob Dernier.

Yet, despite Dernier's run, the Phillies lost, 5-4. So, *I did not find one positive outcome from these 71 substitutions* over two decades of World Series play.

[1] Incidentally, another potential advantage of using a faster runner is to stay out of a double play, with the extra out and/or baserunner enabling the team to score a run they wouldn't have otherwise. That may have been the case for Dernier, but I don't see it as a factor in any of the other 11 run-scoring innings described here.

I did find some negative ones, however. Six of the pinch-runners were thrown out on the bases, costing both a baserunner and an out: four caught stealing, one picked off, and one thrown out trying to score on a foul pop (there were just two successful steals, neither leading to a run).

It's impossible to prove that any of these negative outcomes cost runs or games, but we can estimate the damage, and it is less than I would have thought. I used Pete Palmer's run and win probability tables to analyze the six baserunning blunders, below, with the "expected win %" representing the team's win probability had the runner stayed put compared to its probability after the out, and likewise with the number of expected runs:

World Series Pinch Runners Thrown Out on the Bases, 1970-1989

Year	Gm	Inn	Pinch Runner	Outcome	Expected Win %	Expected Runs	Cost in Wins	Cost in Runs
1972	1	9	Allen Lewis, OAK	CS	.849 → .823	.478 → .095	.026	.383
1972	2	6	Allen Lewis, OAK	CS	.779 → .763	.209 → .000	.016	.209
1972	5	9	John Odom, OAK	Retired	.201 → .000	.494 → .000	.201	.494
1974	2	9	H. Washington, OAK	Pick-off	.160 → .034	.478 → .095	.126	.383
1979	2	9	Matt Alexander, PIT	CS	.575 → .447	.783 → .249	.128	.534
1984	5	8	Luis Salazar, SD	CS	.180 → .125	.209 → .000	.055	.209

So, these six events cost their teams a total of .552 wins and 2.21 runs. But realistically, in retrospect, none of them changed the outcome of a Series. The '72 and '74 A's and the '79 Pirates all won the world championship anyway, and the '84 Padres were crushed in five games.

Furthermore, the replaced player's spot came back up in the batting order on 26 occasions; the substitutes managed only a .240/.269/.280 batting line in those situations. The cost of this is harder to quantify but, for those 26 events, I took the weighted average of the players who were replaced, based on their performances in those particular Series. It came to a .305 batting average, .402 on-base percentage (not counting hit batsmen or sacrifice flies), and .441 slugging percentage. Obviously much better than the marks of the replacement players, but how to translate that into runs and/or wins? Using Bill James' basic Runs Created formula, the difference is roughly 3.97 runs compared to. 1.88.

So, those substitutions resulted in a loss of 2.09 runs. At ten runs per win, that's .21 wins. It's remotely possible that somewhere along the line, a team lost a game or even a series due to such a substitution.

So, all in all, pinch-runners were responsible for one extra run – Dernier's – while costing their teams about 4.3 runs due to reckless baserunning and weakened batting orders.

Now, based on this little study, I wouldn't suggest that the strategy costs four times as many runs as it gains, or that it never makes sense to use a pinch-runner. But, I think it offers preliminary evidence that it has negligible value at best – much ado about nothing – and may actually decrease a team's chances of scoring and winning.

I acknowledge that this is a very limited study. I would love to see someone extend it to include the last 25 World Series, or better yet, regular-season play. Surely there are situations where a pinch-runner has helped a team win a game.

But it didn't happen in any World Series game in the 1970s or '80s.

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Sacrifice Flies, Squeezes, and Stealing Home

Pete Palmer

Taking the extra base from third to home is especially valuable with two outs, because there is so much less opportunity to score the runner afterwards. Why, then, are teams so conservative in those cases, when deciding whether to steal home or score on a sacrifice fly? Here, Pete Palmer gives us a history of his methodology for computing the breakeven points, and then shows us the actual data.

Introduction

I grew up near Boston, but, as an eight year old, I knew nothing of the Red Sox in 1946 when they won the pennant. I started getting interested in baseball stats two years later, collecting baseball cards. Bowman had just revived their card business with a 48-card set, mostly Giants and Yankees, and no Red Sox. For the next five years my main interest, besides playing neighborhood ball, was just in obtaining complete sets.[1]

In 1951, I discovered the Sporting News at a local newsstand, and their baseball guide a few years later. At that time, the Sporting News sold previous guides and registers at cover price. Plus, I found dealers there like Michael Stagno and L.E. Hamlett, who would sell guides back to 1900 for five or ten dollars. So, I had a pretty complete collection by the late fifties.

I spent a lot of time making lists – runs, runs batted in, walks, strikeouts, and so forth, expanding into pitching and fielding as well. I also compiled lists of regular players at each position each year for every team back to 1900, with the help of the guides, and the Little Red Book of Baseball, which listed complete World Series rosters every year.

Later, I began to get interested in analysis. My first project was relating runs to wins. Team run totals for and against were available only as far back as 1920 or so. I determined that it took about ten extra runs to result in one more win. The actual number could vary between nine and eleven – more runs were needed in the case of high-scoring teams – so using ten times the square root of runs per inning by both teams worked a bit better. However just plain ten worked well enough in most cases.

There were no play-by-play records in those days, except for the detailed description of the World Series in the Baseball Guide. I went over thirty-four such games, from 1956 to 1960 to estimate the probability of scoring for the batter, and for a runner on each base.

I came up with these probabilities:

	batter	runner on 1ST	runner on 2nd	runner on 3RD
0 outs	.14	.33	.50	.81
1 out	.12	.29	.38	.62
2 outs	.08	.14	.23	.28

Of course, 34 games was a pretty small sample, so I went more granular. I used the play-by-play data to estimate other, related, probabilities, like going from first to third on a single. advancing on a ground ball, various ways of being out on the bases, etc. I developed a paper and pencil simulation, using the various additional probabilities measured in the play-by-plays, to come up with a more accurate set of figures:

	batter	runner on 1ST	runner on 2nd	runner on 3RD
0 outs	.16	.39	.62	.86
1 out	.12	.26	.43	.66
2 outs	.07	.12	.24	.30

I then used these updated figures to come up with my first set of linear weights, by calculating the run value of a walk, single, etc. The weight was just the difference between the "before" and "after" weights, so that a batter getting to first with none out was worth .23 runs (.39 minus .16), advancing a runner from second to home would be .38 (1.00 minus .62), and so forth.

[1] In 1953 or 1954, I sold my five Bowman complete sets to Goodwin Goldfaden for $10, which seemed like a good price at the time. After inflation, that's about $100 today. The current market price could be in the $50,000 range. Oh well.

However, I eventually compared these results to the actual run totals for teams, I found the low scoring teams were too high and the high scoring teams too low. I realized I was doing it all wrong.

Fundamentally, there are two parts to each batting event. The first part is the advancement of players, as measured above. The second part, which is crucially important, is the fact that if a batter gets on base, an additional batter comes to the plate. And that batter could lead to other batters, and so on. Since an average batter's on-base percentage is about one third (.333), the total number of additional batters is 1/3 plus 1/9 plus one 1/27, and so on ... which is equal to exactly one half.

So every time a batter gets on base, he adds one and a half batters more than when he makes an out. This shows the power of on-base percentage. The average number of additional batters is one half (since two-thirds of the time, it's zero, and one-third of the time it's 1.5). So, compared to the average of 0.5, a hit is worth +1 batter and an out is worth -0.5 batters.

So, if a leadoff batter singles, he gets .23 runs for getting himself to first base, plus an additional .16 runs for bringing up one more batter than average.

This shows up automatically if you change the table from run scoring probability to the expected number of runs . These are the numbers my paper simulation came up with using the 1956-60 model:

Run Expectation	batter	runner on 1ST	runner on 2nd	runner on 3RD
0 outs	.48	.82	1.07	1.32
1 out	.27	.50	.70	.94
2 outs	.10	.22	.35	.38

Run Expectation	1st + 2nd	1st + 3rd	2nd + 3rd	loaded
0 outs	1.43	1.72	1.94	2.35
1 out	0.91	1.14	1.35	1.58
2 outs	0.48	0.50	0.62	0.71

With these new linear weights, team estimates corresponded well to actual runs.

Looking at the one-runner case, you can see that for the most part, advancing one base is worth about a quarter of a run, with the exception of 3rd to home with two out:

Advancement Value	batter	runner on 1st	runner on 2nd	runner on 3rd
0 outs	.34	.25	.25	.16
1 out	.23	.20	.24	.33
2 outs	.12	.13	.03	.72

Look at moving from third to home with none out. On third, the "Run Expectation" table shows expected runs as 1.32. If you score the run, you increase that to 1.48 – 0.48 for the new situation (nobody on, nobody out), plus 1.00 for the actual run. The difference between the two is the ".16" in the "Advancement Value" table above.

But, with two outs, scoring the runner is *almost four times as valuable* – .72 runs instead of .16. It's by far the most important advance.

Win Probabilities

In the early seventies, I was finally able to do some work on a computer, thanks to the MITRE Corporation, where I worked. I wrote a simulation which was driven by league average walks and hits, plus the various probabilities from the play-by- play which created a run potential table for any set of inputs. Using these tables, I could create win probabilities for each game situation.

There are actually two methods to get those probabilities. One is called Monte Carlo, where you get a random number for each event and play many games through to the end. The other is what I originally called "exhaustive probabilities", where instead of selecting one of many possible outcomes for each event, I divided the flow proportionally by the probability of each event happening. I later learned this method is actually called a "Markov Chain", after Andrey Markov, who developed the theory over 100 years ago.

At any rate, the variation due to chance in a Monte Carlo simulation of one year, say 750 runs, is actually the square root of twice the number of runs, so the standard deviation would be almost 40, a pretty big number if you are trying to measure small differences. You could wind up with a random, spurious difference of over 80 runs, five percent of the time, just due to chance. You can reduce this factor by running multiple simulations, but you can never reduce it to zero. In contrast, the Markov Chain method gives an exact answer based on the input parameters after only one run, which is its strongest advantage.

I also took advantage of MITRE's fine technical library to look up articles on baseball. Here I discovered the work of George Lindsey, who in the sixties calculated run probability tables, linear weights and win probability values, all using data he collected from radio accounts of over 350 major league and International League games in 1959 and 1960. (He did not include a negative value for an out however, which is crucially important.) Lindsey had several articles published on baseball; his most important was "An Investigation of Strategies in Baseball."[2] It was included with many other pieces in the bibliography of *The Hidden Game of Baseball*.[3]

Advancing Runners

The main point from all those preliminaries: scoring from third with two out is much, much more valuable then with one out or no outs. And, that seems to have been overlooked by major league teams, judging by their actual in-game strategies.

I checked some 25,000 sacrifice fly situations from 2001-2014, using Project Scoresheet-style hit locations, which classify flies as short (200 to 250 feet), medium (250-300), deep (300-350) or extra deep (350 or more).

Should you try for home on a sac fly? The breakeven point with one out – the caught fly being the first out – is around 70%, meaning that it's worthwhile to try if you have at least a 70 percent chance of making it home safely[4]. But with two outs, the breakeven is only 30 percent, because that's in line with the lowered probability that runner will score later in the inning anyway.

1 out

	RE stay	RE score	RE out	breakeven %
3 only	.89	1.23	.08	70
1-3	1.09	1.49	.19	69
2-3	1.33	1.60	.28	80
Full	1.48	1.83	.36	76

2 out

	RE stay	RE score	RE out	breakeven %
3 only	.33	1.08	.00	31
1-3	.46	1.19	.00	39
2-3	.53	1.28	.00	41
Full	.69	1.36	.00	51

[2] Operations Research Journal, July-August 1963.

[3] Editor's note: "The Hidden Game of Baseball," which Pete co-wrote with John Thorn in 1984, is one of the sabermetric classics. It has just been reprinted, with an updated appendix of stats, and can be purchased here: http://amzn.to/1RxyiIs

[4] The actual breakeven point varies around 70%, depending on what other runners are on base. And, of course, the identities of the runner, outfielder, catcher, and subsequent batters also affect the calculation.

But ... the real-life success rate is well over 90 percent, in all situations! And, there is only a small increase in attempts with two outs versus one out.

1 out

	stay on 3rd	safe	out	go %	safe %
Unknown	1	0	0	0	0
Infield	24	1	0	4	100
200	821	197	17	21	92
250	582	1785	39	76	98
300	44	2658	0	98	100
350+	0	1016	0	100	100

2 out

	stay on 3rd	safe	out	go %	safe %
Unknown	4	13	0	76	100
Infield	38	5	0	12	100
200	1769	656	72	29	90
250	1003	4744	200	83	96
300	108	6383	13	98	99.8
350+	7	2452	0	99	100

The short and medium cases are the only interesting ones, since deeper flies show runners are sent almost 100 percent of the time and successful almost every time. As you can see, with two outs, the attempt rate on short flies increased only from 21 to 29 percent, and the success rate dropped only slightly, from 92 to 90. Medium flies saw an increase in attempts from 76 percent to 83 percent, and only a small drop in success from 98 percent to 96.

Since the actual success rates are so high, it is difficult to tell what the results would be if more runners were sent, but it seems safe to conclude that it would be worthwhile to increase the number of attempts. Even with one out, it appears more risk-taking would be advised.

So why don't teams go for it more? Perhaps managers feel it's safer to do as everyone else does, rather than be criticized for trying something when it doesn't work out. It is acceptable for a batter to fail two thirds of the time, or a base stealer to fail one third of the time, but scoring after a fly is supposed to be perfect.

Still, it's not a huge deal. There were only 2,772 cases where a runner held up with two outs and a short or medium fly ball. Over 15 years and 30 teams, that's about four cases a year, per team. So even if you went all four times and were successful three, you would only gain two runs. In the one-out cases, you would need two out of three just to break even.

Stealing Home

Trying to steal home involves the same logic, and the breakeven points are the same.

I looked at all the steal of home attempts over the same 2001-2014 period. Since we have pitch-by-pitch data back to 1988, I was able to separate the failed squeeze attempts from the straight steals based on whether the batter missed the bunt. Since it was not possible to determine if a pickoff was the result of a stolen base attempt, I measured them but did not count them. I did count the pickoff/caught stealing cases. (Official rules state that if a runner is picked off and makes an attempt to advance, it is a POCS; otherwise, it's just a pickoff.)

0 out

	sb	cs	pocs	pick	success	breakeven
Normal	5	8	3	21	31.3	~70
Squeeze	1	2	1	0	25.0	~70

1 out

	sb	cs	pocs	pick	success	breakeven
Normal	73	211	21	85	23.9	~70
Squeeze	5	85	5	2	5.3	~70

2 outs

	sb	cs	pocs	pick	success	breakeven
Normal	97	113	55	34	36.6	~30
Squeeze	1	2	0	0	33.3	~30

As you can see, even from this limited data, stealing home with two outs could be a good play. But with one out, at actual success rates, it is foolish.

Yet, actual attempts with one out are much higher – fifteen percent in raw numbers, but, taking opportunities into account, almost double! And this despite the fact that (a) the success rate is lower, and (b) the breakeven rate is more than twice as high!

So why are teams trying to steal home with one out? I can't answer that one.

Suicide Squeeze

Starting in 2004, we have pretty good information on when the runner was off with the pitch. There have been only 1,822 squeeze attempts in the eleven years 2004-2014 – about five or six per team per year. Of those, only 376 were suicide squeezes, about once a year per team. Almost all of the squeezes occurred with one out, resulting in a small overall loss in win probability and potential runs.

For suicide squeezes, the overall success rate was 65%. The breakeven percent is difficult to calculate because of the number of possible outcomes, but is probably around 70%. If you just treat a success as "one run in and bases empty," with a failure being "runner on first," the breakeven point works out to 82%. But, often, both runners wind up safe – that happened about 11 percent of the time – and that's what brings the breakeven down to from 82 percent to 70.

Here's the nobody-out case:

Suicide squeeze, 0 out

	stay	score	out	WP bef	WP aft	WP diff	RE bef	RE aft	RE diff	ScDif
all	21	8	4	71.3	68.1	-3.2	1.80	1.48	-0.32	0.24
foul	0	0	0							
miss	0	1	3	69.2	53.3	-16.0	1.59	0.76	-0.84	-0.25
bunt	0	0	1	89.6	82.6	-7.0	1.70	0.81	-0.89	1.00
pop	2	0	0	84.9	79.7	-5.2	1.83	0.73	-1.11	2.00
sac	2	5	0	80.0	80.6	.7	1.82	1.68	-0.14	1.43
hit	0	2	0	81.0	89.3	8.4	2.01	2.82	0.81	0.00
error	0	0	0							
miss +	8	0	0	68.7	66.9	-1.8	1.71	1.54	-0.18	0.13
foul +	9	0	0	60.8	57.1	-3.7	1.89	1.54	-0.35	-0.78

Row headings: , "WP" is the win probability in percent, before and after the attempt, then the difference. "RE" is the run expectation, before and after, then the difference. "ScDif" is the actual score of the game before the play (batting team runs minus pitching team runs). That column helps to show why the "before" win probabilities seem so high – it's because the squeeze was so often attempted by the team with the lead.

Columns: "foul" and "miss" are foul bunts and missed bunts that ended the squeeze attempt. The "foul+" and "miss+" at the bottom are those that did not end the possible attempt – just the batter winding up with an extra strike on him.

Here's one out and two outs:

Suicide squeeze, 1 out

	stay	score	out	WP bef	WP aft	WP diff	RE bef	RE aft	RE diff	ScDif
all	234	232	86	76.8	76.0	-0.8	1.08	0.95	-0.13	1.31
foul	12	0	0	70.2	60.4	-9.8	1.09	0.44	-0.65	0.75
miss	2	6	73	75.6	67.8	-7.7	1.07	0.28	-0.79	1.17
bunt	1	0	10	72.0	65.9	-6.1	1.08	0.37	-0.71	1.27
pop	22	0	1	76.3	65.6	-10.7	1.04	0.01	-1.03	1.26
sac	1	189	0	77.7	81.2	3.5	1.08	1.31	0.23	1.36
hit	0	34	0	76.1	82.4	6.3	1.09	1.75	0.66	1.26
error	1	3	2	74.5	85.8	11.3	1.25	2.02	0.77	0.83
miss +	4	0	0	85.4	79.9	-5.6	1.13	0.41	-0.73	1.25
foul +	191	0	0	77.1	75.6	-1.5	1.09	0.90	-0.19	1.37

Suicide squeeze, 2 out

	stay	score	out	WP bef	WP aft	WP diff	RE bef	RE aft	RE diff	ScDif
all	24	2	1	62.3	60.2	-2.2	0.45	0.26	-0.19	0.59
foul	0	0	0							
miss	0	0	1	62.8	50.0	-12.8	0.75	0.00	-0.75	0.00
bunt	4	0	0	60.7	51.8	-8.9	0.47	0.00	-0.47	1.00
pop	0	0	0							
sac	0	0	0							
hit	0	2	0	52.8	71.6	18.9	0.44	1.34	0.90	0.00
error	0	0	0							
miss +	14	0	0	74.9	72.8	-2.1	0.41	0.26	-0.15	1.29
foul +	6	0	0	37.4	34.1	-3.3	0.46	0.09	-0.37	-1.00

Safety Squeeze

The safety squeeze was tried 1,442 times, about 60% of those coming with one out. The overall result was somewhat worse than the suicide case. The safety squeeze eliminates the chance of the runner being out at the plate after a missed bunt, but the percentage of runners scoring on a good bunt is much lower, only 40 percent overall. The two out case, when the batter was bunting for a hit, was the most successful, just about breaking even. The fact that the breakeven point is much lower with two outs makes the attempt more worthwhile. Also, the bunters in this case were probably better than in the other two cases.[5]

Here are the full safety squeeze results:

Safety squeeze, 0 out

	stay	score	out	WP bef	WP aft	WP diff	RE bef	RE aft	RE diff	ScDif
all	564	75	17	71.5	69.7	-1.8	1.72	1.51	-0.21	0.63
foul	25	0	0	68.2	62.7	-5.5	1.73	1.12	-0.61	0.40
miss	11	0	0	71.0	66.4	-4.5	1.79	1.17	-0.63	0.91
bunt	16	0	17	71.8	64.0	-7.7	1.79	1.02	-0.78	0.45
pop	15	0	0	73.3	67.0	-6.3	1.70	1.01	-0.69	1.00
sac	160	49	0	70.7	69.3	-1.4	1.73	1.54	-0.19	0.69
hit	6	24	0	67.5	73.2	5.7	1.73	2.33	0.59	0.10
error	2	2	0	82.4	85.4	3.0	1.67	2.19	0.52	1.75
miss +	43	0	0	70.2	68.5	-1.6	1.69	1.51	-0.18	0.33
foul +	286	0	0	72.7	71.1	-1.7	1.71	1.53	-0.18	0.69

[5] The times when there was a missed or fouled bunt in a squeeze situation are included in all breakeven calculations, because the inning is weakened by the batter taking an extra strike.

Safety squeeze, 1 out

	stay	score	out	WP bef	WP aft	WP diff	RE bef	RE aft	RE diff	ScDif
all	994	354	87	68.7	67.0	-1.8	1.13	0.93	-0.20	0.79
foul	39	0	0	71.2	66.2	-5.0	1.11	0.47	-0.64	1.36
miss	12	0	10	69.1	63.2	-5.9	1.10	0.35	-0.74	0.59
bunt	57	5	73	71.0	63.9	-7.1	1.15	0.44	-0.71	0.93
pop	57	4	4	69.7	62.5	-7.2	1.13	0.46	-0.67	0.89
sac	224	239	0	69.0	68.7	-0.3	1.11	1.02	-0.09	0.85
hit	10	91	0	67.1	74.5	7.4	1.14	1.84	0.69	0.47
error	5	15	0	69.1	78.2	9.1	1.21	2.06	0.86	0.90
miss +	109	0	0	66.1	62.5	-3.6	1.16	0.87	-0.29	0.45
foul +	481	0	0	68.4	66.0	-2.5	1.14	0.88	-0.26	0.77

Safety squeeze, 2 out

	stay	score	out	WP bef	WP aft	WP diff	RE bef	RE aft	RE diff	ScDif
all	607	109	4	60.3	60.4	0.2	0.46	0.45	-0.01	0.56
foul	5	0	0	46.8	41.1	-5.7	0.47	0.00	-0.47	-0.60
miss	5	0	0	70.2	67.6	-2.7	0.44	0.12	-0.32	1.40
bunt	114	2	4	61.3	56.7	-4.6	0.45	0.02	-0.44	0.67
pop	20	0	0	56.3	50.2	-6.1	0.45	0.00	-0.45	0.30
sac	0	0	0							
hit	10	98	0	61.8	72.1	10.3	0.44	1.26	0.83	0.56
error	3	9	0	57.0	65.4	8.4	0.48	1.50	1.03	0.25
miss +	93	0	0	61.7	60.9	-0.8	0.48	0.35	-0.12	0.74
foul +	357	0	0	59.5	58.6	-0.9	0.46	0.37	-0.09	0.51

Conclusions

So, over all, these cases – sac flies, steals, and squeezes – there are really no huge blunders here, except for stealing home with one out. Most of the situations covered only come up a few times a year per team. There could be a little more aggressiveness with a runner on third and two out.

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Back issues of "By the Numbers" are available at the SABR website, at http://sabr.org/research/statistical-analysis-research-committee-newsletters, and at editor Phil Birnbaum's website, www.philbirnbaum.com .

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