# Tom Brady and Siméon Poisson: An Unlikely Duo

Lillian J. Cullen[1], Valentina H. Hogenhuis[1], Emily S. Garcia[1] and Paul Martin Sommers[1]

[1]Middlebury College

## ABSTRACT

Seven-time Super Bowl champion Tom Brady announced his retirement from the National Football League (NFL) on February 1, 2022. Forty days later, he changed his mind about retiring. Tom Brady's records through twenty-two NFL seasons are numerous and well known to fans of professional football. During his first twenty seasons with the New England Patriots and, more recently, the Tampa Bay Buccaneers, the number of Tom Brady touchdown passes per game has something in common with a nineteenth century French mathematician, engineer, and physicist, Siméon Denis Poisson (1781 – 1840). In this paper, the authors hypothesize that the number of Tom Brady touchdown passes per regular season game (all games, wins or losses) and the corresponding number per playoff game (all games, wins or losses) have followed a Poisson probability distribution. The close correspondence of these statistics to a Poisson distribution is stunning and astonishing, two words that have also been used to describe the 44-year-old quarterback during his playing career.

## Introduction

It's official. On February 1, 2022, at 44 years of age, Thomas Edward Patrick Brady Jr. (born August 3, 1977) announced his retirement from the National Football League (NFL) after twenty-two seasons (twenty with the New England Patriots and two with the Tampa Bay Buccaneers). The sixth round draftee in 2000 is arguably the greatest quarterback of all time. During his career, Brady passed for 97,569 yards (84,520 in the regular season, 13,049 in the postseason), completed 8428 of 13172 passes for a 63.98 completion rate (7263 of 11317 in the regular season, 1165 of 1855 in the postseason), and threw 710 touchdown passes (624 in the regular season, 86 in the postseason). He collected seven Super Bowl rings (six with the New England Patriots and one with the Tampa Bay Buccaneers) and five Super Bowl Most Valuable Player (MVP) awards. He was selected to fifteen Pro Bowls and he won three league MVP awards.

Forty days later, Tom Brady changed his mind. On March 13, 2022, he announced his "unretirement" on social media.

Many people have written about Tom Brady, his success, lifestyle, and work ethic (see, for examples, Pierce [1], Mullins [2], Schatter [3], Sherman and Wedge [4], and Abdo [5]). Sommers [6] compared his averages (completions, attempts, completion percentage, passing yards, yards per attempt, touchdowns, and interceptions per game) before 2008 (when Brady tore his ACL in the first game of the 2008 season) and the period 2009 through 2017. The comparisons revealed no evidence of a decline in any of the aforementioned categories.

Few players have competed in more than 300 NFL games. The duration of Tom Brady's career through twenty-two seasons (365 games) is not only remarkable, but also provides an abundance of data about his performance and consistency. One cannot help but wonder if any aspects of his performance follow a pattern? In this paper, the authors seek to explore if the number of touchdown passes thrown by Tom Brady per game over his career to date follow a Poisson theoretical model, so named after Siméon Poisson (1781 – 1840), a French mathematician, whose probability distribution first appeared in his 1837 paper, "Research on the Probability of Criminal and Civil Verdicts." His approximation to the binomial distribution, now known as the Poisson probability distribution, is often used to estimate the number of occurrences over a specified interval of time or space. In our case, the random variable will be Tom Brady's number of passing touchdowns in a game.

## The Data

The game logs for all 365 of Tom Brady's career games are from espn.com [7]. In 318 regular season games, Tom twice threw as many as six touchdowns per game; in seventy-five regular season losses, he never threw more than four touchdowns in a single game. In forty-seven playoff or postseason games, Tom once threw for four touchdowns and once threw for six, but never threw for five. And, in twelve playoff losses, he never threw more than three touchdowns.

The number of touchdown passes thrown in a game is here assumed to be a discrete random variable. The probability that Tom Brady throws a touchdown pass is small (relative to the large number of all possible passing and rushing plays) and assumed to be the same in any game. Moreover, the number of touchdown passes in one game is assumed to be independent of the number Tom Brady throws in any other game, although there will always be some variation among NFL teams in allowing passing touchdowns. (In 2021, for example, the Buffalo Bills gave up only twelve passing touchdowns, but the Washington Commanders, then known as the Washington Football Team, gave up thirty-four.) Under these assumptions, is the number of Tom Brady's touchdown passes per game Poisson? Surprisingly, the answer is yes, however we group his games – regular season or postseason, win or lose.

## Methodology

The Poisson distribution is a discrete probability distribution which has the following formula:

(1) $$p(X = x) = \frac{e^{-\lambda}\lambda^{x}}{x!}, \quad x = 0, 1, 2, \ldots$$

where λ denotes the mean number of touchdown passes per game or the expected value of the Poisson distribution. In Table 1, a Poisson distribution is shown to be an appropriate model for the number of touchdown passes Tom Brady threw per game in his 365-game career.

The expected value of the Poisson distribution is estimated by

(2) $$\hat{\lambda} = \frac{\sum x_i O_i}{n} = 1.9452$$

where $n = 365$. Small expected values ($E_i$) less than 1.0 can cause problems in a $\chi^2$ goodness-of-fit test. In Table 1, all expected frequencies are greater than 1.0 and hence obviated the need to pool adjacent classes until all expected frequencies were at least 1.0 as suggested in [8].

How well does the observed frequency distribution conform to the Poisson distribution? The null hypothesis is that the discrepancies between them are due to chance, that is, the observed frequencies are compatible with the expected frequencies. The value of the test statistic is

(3) $$\chi^2_{calculated} = \sum \frac{(O_i - E_i)^2}{E_i} = 6.921$$

The number of degrees of freedom is, in general, equal to $k$ – the number of estimated parameters – 1, where $k$ is equal to the number of classes or categories. We used $\bar{x}$ from the actual distribution to estimate λ in the Poisson distribution. Hence, for the distribution shown in Table 1, $k = 7$ and the number of degrees of freedom is therefore 7 - 1 - 1 or 5. Since the critical value of $\chi^2$ for a significance level of $\alpha = .05$ is $\chi^2_{.05,5} = 11.071$ and exceeds the value of the test statistic in equation (3), it follows that we cannot reject the null hypothesis. In other words, the probability is greater than .05 (in particular, .227) that the discrepancies between the observed frequencies and the expected frequencies based on the Poisson probability distribution could be due to chance.

### The Results

The results of nine different $\chi^2$ goodness-of-fit tests are reported in Table 2. All degrees of freedom were adjusted to account for, first, the estimated parameter ($\bar{x}$ in place of λ) for the Poisson distribution and, second, when adjacent categories had to be combined because expected frequencies were less than 1.

For all nine tests involving all games – regular season or postseason, wins or losses – in Tom Brady's career, the Poisson model provided an excellent fit. In only the case of career wins, the *p*-value of the test was below .10, but still above our chosen significance level of $\alpha = .05$. For career wins, the category corresponding to 2 passing touchdowns per game contributed the most to our test statistic. In this case, the observed number of career games with 2 passing touchdowns was 89 while the expected number of such games was only 74.9.

## Concluding Remarks

Quarterback Tom Brady retired after twenty-two seasons and soon thereafter changed his mind about retiring. After twenty-two seasons, he holds NFL records for games started, playoff games, wins, career touchdown passes, career passing yards, pass completions in a season, just to name a few. An analysis of the number of times he completed passing touchdowns per game shows a clear and consistent pattern: surprisingly, they follow a Poisson probability model. Tom Brady frequently connected with Rob Gronkowski (who, after eleven seasons, announced in June 2022 *his second* retirement from the NFL). Until now, few fans of the game knew of Tom Brady's connection with Siméon Poisson.

**Table 1. The Number of Touchdown Passes in Tom Brady's Career**
**November 23, 2000 – January 23, 2022**

| ***Touchdowns*** ($x_i$) | ***Observed frequency*** ($O_i$) | ***Poisson probability***[a] ($p_i$) | ***Expected frequency*** ($E_i = 365 \times p_i$) |
|---|---|---|---|
| 0 | 49 | .1430 | 52.18 |
| 1 | 90 | .2781 | 101.50 |
| 2 | 112 | .2705 | 98.72 |
| 3 | 73 | .1754 | 64.01 |
| 4 | 31 | .0853 | 31.13 |
| 5 | 7 | .0332 | 12.11 |
| 6 | 3 | .0108 | 3.93 |

[a] The expected value of the Poisson distribution is estimated by $\bar{x} = 1.9452$ where $n = 365$.

**Table 2. The Number of Touchdown Passes in Tom Brady's Career, Chi-Squared Goodness-of-Fit Tests to a Poisson Probability Distribution**

| *Group* | *Number of games* | *Average number of touchdowns* | $\chi^2_{calculated}$ | *p-value* |
|---|---|---|---|---|
| Career | 365 | 1.945 | 6.921 | .227 |
| Career win | 278 | 2.147 | 10.060 | .074 |
| Career loss | 87 | 1.299 | 1.051 | .789 |
| Regular season | 318 | 1.962 | 5.583 | .349 |
| Regular season win | 243 | 2.169 | 7.760 | .170 |
| Regular season loss | 75 | 1.293 | 0.678 | .878 |
| Playoffs[a] | 47 | 1.830 | 4.305 | .366 |
| Playoff win[a] | 35 | 2.000 | 5.864 | .210 |
| Playoff loss | 12 | 1.333 | 3.377 | .185 |

[a] The expected number corresponding to an observed frequency of 6 passing touchdowns per game was less than 1.0. The categories corresponding to an observed frequency of 5 or 6 passing touchdowns per game were therefore pooled into one category.

## References

1. C. P. Pierce, *Moving the Chains: Tom Brady and the Pursuit of Everything*, Farrar, Straus and Giroux, 2007.

2. S. Mullins, *Tom Brady 172 Success Facts — Everything You Need to Know about Tom Brady*, Emereo Publishing, 2014.

3. T. Schalter, *Tom Brady Will Be Bad Eventually*, FiveThirtyEight, 2017 https://fivethirtyeight.com/features/tom-brady-will-be-bad-eventually

4. C. Sherman and D. Wedge, *12: The Inside Story of Tom Brady's Fight for Redemption*, Little, BBrown and Company, 2018.

5. K. Abdo, *Tom Brady*, ABDO Group, 2018.

6. P. M. Sommers, "Has Tom Brady Passed His Prime?" *Open Journal of Statistics*, Vol. 8 (2018), pp. 831-836.

7. Tom Brady's career statistics are from espn.com at https://www.espn.com/nfl/player/gamelog/_/id/2330/tom-brady

8. G. W. Snedecor and W. G. Cochran, *Statistical Methods*, 6th edition, Ames, Iowa: Iowa State University Press, 1967.