

# The GOAT of the GOATs

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## Introduction

Growing up, we would debate sports on the basketball court as we were waiting for our turn to play. “Is LeBron better than MJ?” “Is Messi better than Ronaldo?” “Is Brady the greatest to ever do it?” While these questions were always heavily debated, one question reigned above them all: “Who is the GOAT of ALL sports?” In this report, we take a gander at this question across the 3 largest American sports: Basketball, Football, and Hockey. Restricting our analysis to years after 1980 to adjust for data availability, we first use statistical techniques to determine a GOAT for each sport before determining the GOAT of the GOATs. Through our analysis, we found that the basketball GOAT was Michael Jordan, the football GOAT was Tom Brady, and the hockey GOAT and the GOAT of the GOATs was Wayne Gretzky, the great one.

## Data

We utilized season-by-season player data from three websites - basketball-reference, pro-football-reference, and hockey-reference - for basketball, hockey, and football respectively, focusing on metrics like points, assists, and quarterback rating. This data was combined into sport-specific datasets along with career-wide championships and awards for each player. For instance, awards from before and after 1980 were included for players active in that year, and total seasons played were calculated to assess players' 'longevity' across their careers. Additionally, advanced metrics such as win shares and utilization rate were used. We filtered football to focus solely on quarterbacks, given their high value. We also introduced a "TD/INT" column to calculate the touchdown-to-interception ratio, a critical metric for evaluating quarterback efficiency.

## Exploratory Data Analysis

Coming to our graphical analysis of the data, we present graphs from each dataset to help our analysis.

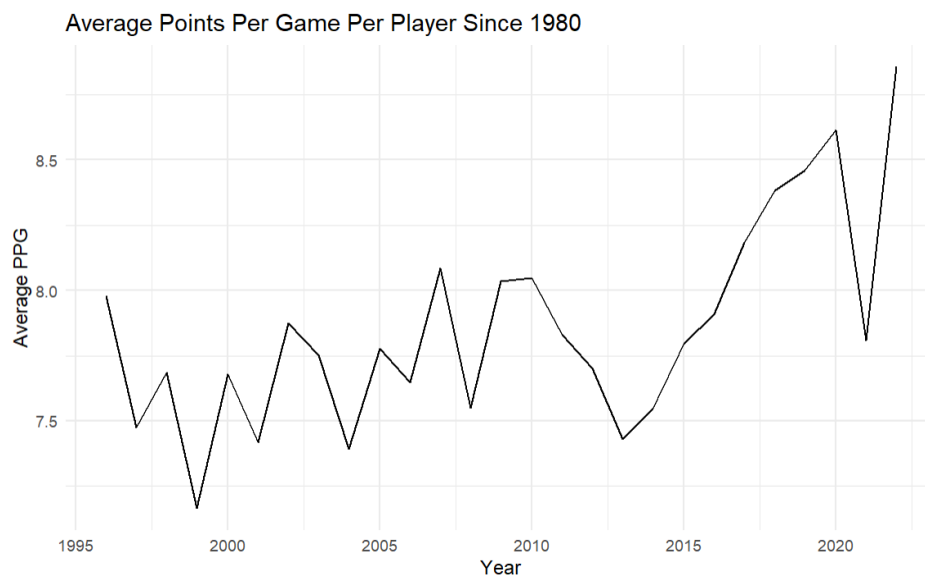


Image 1: Year vs. Points Per Game Per Player in Basketball

Looking first at the graph of Points Per Game (PPG) over time, we see that PPG has increased as players have embraced the 3-point shot as well as getting to the free throw line (thanks James Harden and Joel Embiid). This reflects a need to adjust for eras of the game: Michael Jordan played in an era where the 3-point shot wasn't nearly as prevalent, but he still has the highest PPG of all time – a remarkable feat.

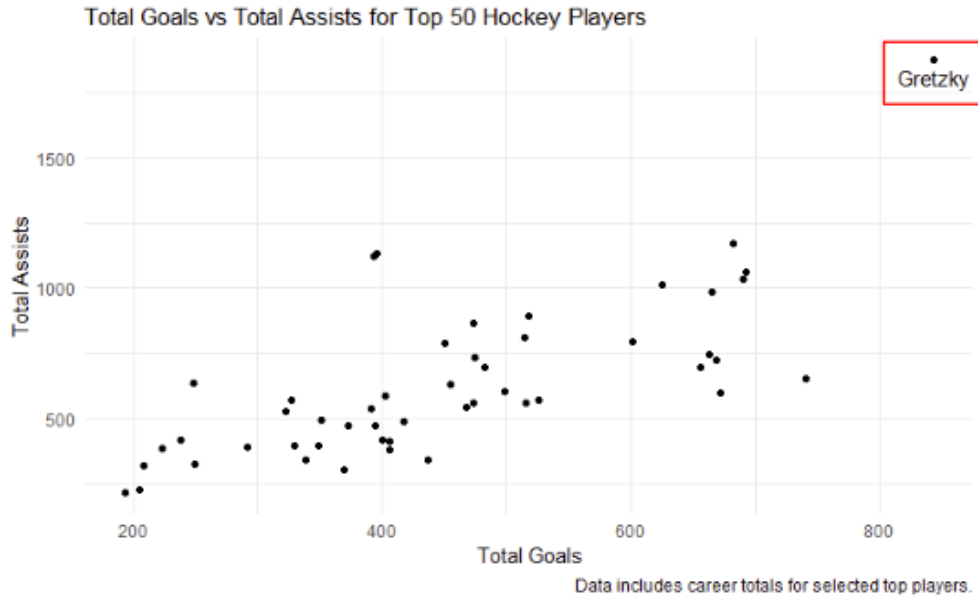


Image 2: Total Goals vs. Total Assists in Hockey

Looking at the graph of assists vs. goals in hockey, we are reminded that even if we get rid of all of Wayne Gretzky's goals, he still has the most points in NHL history. This is clearly represented in the scatterplot and shows us the level at which Gretzky dominated throughout his career.

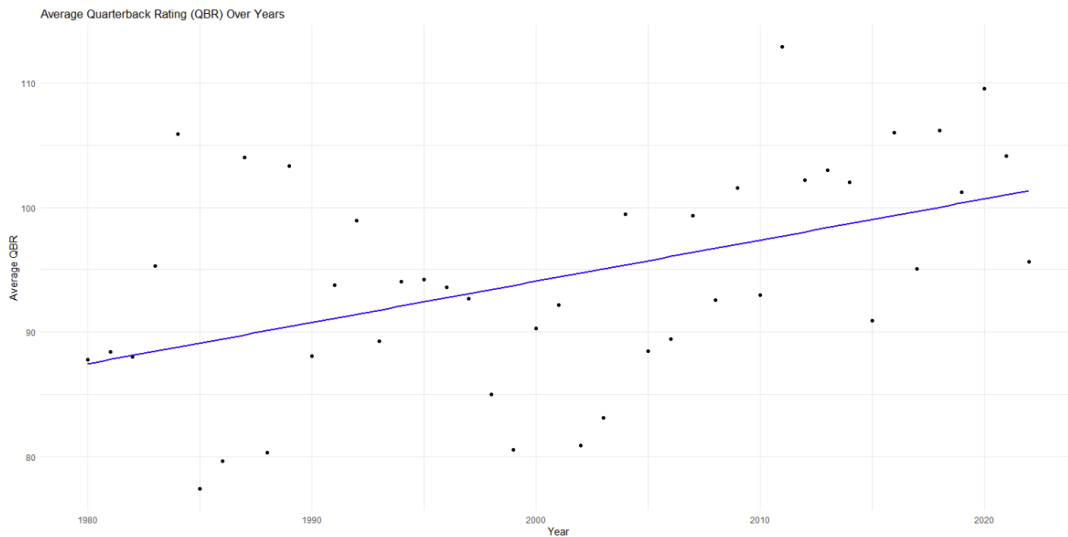


Image 3: Year vs. QBR in Football

Looking at the quarterback rating (QBR) over time, we see an increase as we move towards the present day. In the modern game, the offense is more centered around passing, and two of the four metrics that make up QBR go up as offenses become more pass heavy.

## Methods

To compare the greatest athletes across sports, we defined four categories, each contributing to an overall "GOAT" score.

### Longevity

The first category, "Longevity," is measured by the number of seasons played, reflecting the notion that the greatest players tend to dominate for extended periods. We scaled longevity for each sport, assigning the longest-tenured players a score of 100 and adjusting downward accordingly. This measure is purely quantitative, representing a straightforward count of seasons without associated uncertainty.

### Performance Score

The second category we defined is "performance score". Performance Score is a weighted aggregate of the most important stats for each sport across the best 5 years of a player's career. Prior to calculating the score, the stats across years are adjusted. This adjustment fits linear models to each year's worth of data and then calculates the residuals of the data, which removes the underlying temporal trend in the data. Thus, the residuals obtained from the model represent the adjusted stat values that are independent of the year-to-year trend, and including these adjusted stat values in the performance score calculation helps to account for any potential biases or variations in the stats across different years or eras. This gives us a score for the period in which a given player dominated the most above their peers.

In order to account for uncertainty, we ran 500 simulations using a bootstrapping framework. Assuming that each player's performance over their career was normally distributed, we recalculated residuals for every simulation, assuming a mean of the coefficient in our regression and a standard deviation equal to each player's variance over their career. The upper and lower bounds from these simulations give us confidence estimates and allow us to determine the range of outcomes from our models, which in turn gives us an idea of the uncertainty present in the model. These scores were scaled for each sport, with the most dominant players receiving a score of 100.

For each sport, we defined Performance Scores using sport-specific statistics, ensuring a nuanced evaluation of player impact. In basketball, the score combines points, assists, rebounds, steals, blocks, usage rate, true shooting, and player efficiency rating, with the most significant emphasis on points, as shown in the first appendix image. Hockey's score includes goals, assists, total points, power-play goals, shots on goal, and game-winning goals, prioritizing goals and assists to highlight scoring and playmaking, especially in clutch situations as depicted in the second appendix image. For American football, the score is derived from passing yards, yards per attempt, completion percentage, touchdowns, interceptions, and quarterback rating, adjusted for era differences and weighted to emphasize yards and touchdowns using a

fantasy football scoring approach, as detailed in the third appendix image. This structure accounts for each sport's unique dynamics and player roles.

## Consistency

The third category in our analysis is "consistency," defined as a player's ability to maintain high performance for an extended period. A GOAT not only dominates in their prime but also ranks among the top 10 or 15 players throughout most of their career. To measure consistency, we used the coefficient of variance, a standardized measure of dispersion calculated as the standard deviation divided by the mean. This ratio allows for comparing variability in a player's performance stats over their career. The consistency score is derived by taking the inverse of the sum of the coefficients of variance for chosen stats, favoring players with lower variability. Since the coefficient of variance involves straightforward calculations of mean and standard deviation, no uncertainty measurement was needed. A residual "growth score" was calculated from the average slope and correlation coefficient of a linear regression across all variables over time, intended to reflect a player's statistical improvement, which also contributes to the overall "GOAT Score." Assuming a normal distribution for the performance of a player over time, we accounted for uncertainty in the growth score by using the in-built standard errors from the regression output.

## Winningness

The last category we defined is "winningness". Winningness is initially defined as the weighted product of the number of championships and the number of MVPs that a given player has throughout their career. Given that all of these sports are team sports, we decided to weight MVPs 50% more than championships as the MVP is an individual award. It is important to note here that we considered the total number of awards and championships that a player won throughout their career as opposed to just the ones they won after 1980. Given that winningness, similar to longevity, is simply a weighted number, there is no uncertainty to measure.

## GOAT Score

The final step in our analysis is calculating the GOAT Score for each player, a comprehensive metric that combines longevity, performance score, consistency, and winningness, each weighted to emphasize different aspects of excellence. Performance and winningness scores are heavily weighted to reflect peak capabilities and impact, while consistency and longevity scores are adjusted by performance rank percentage to reward sustained excellence or penalize underperformance. Additionally, a minor weight (0.1) is assigned to the growth score, representing career progression, and to the interaction between performance and consistency scores, emphasizing consistent high performance.

We normalized the GOAT Scores to a mean of zero and adjusted by standard deviation. The formula-driven nature of the GOAT Score means it inherently lacks uncertainty, though uncertainties within its components, like performance and growth scores, are specifically quantified.

# Results

## Basketball

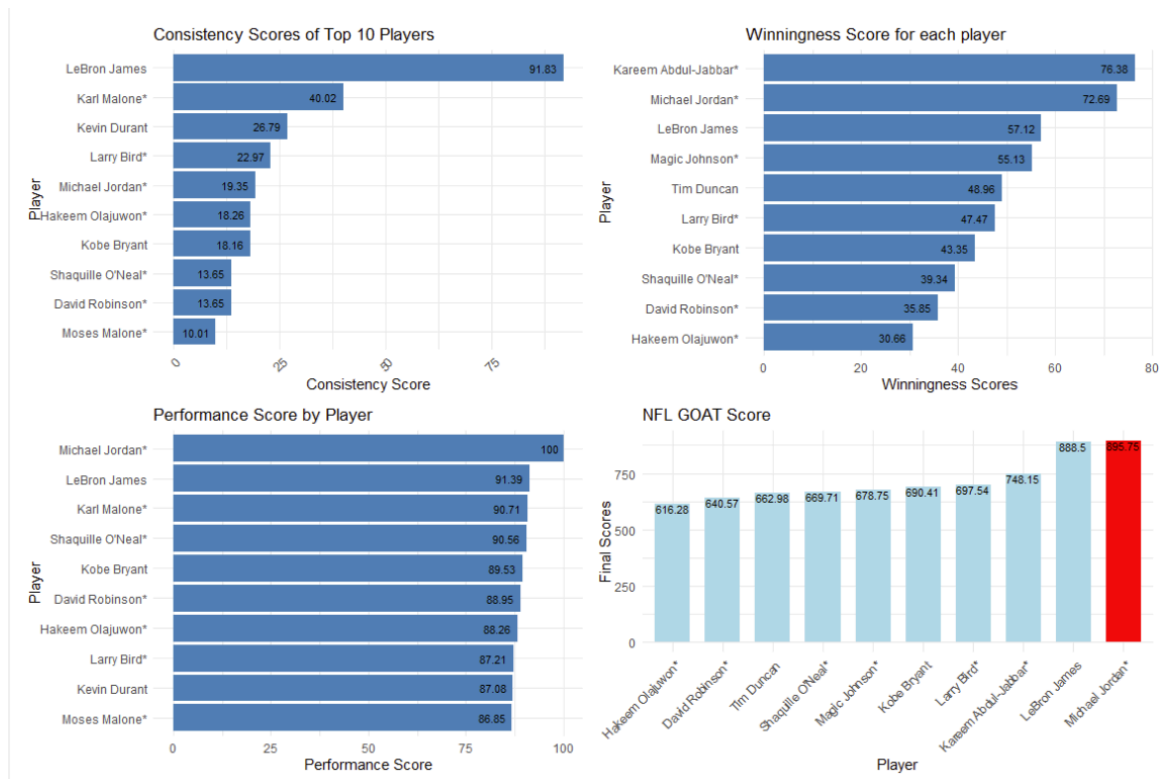


Image 4: Basketball analysis final plots of overall consistency, winningness, performance, and GOAT Score

In basketball analysis, LeBron James excels with the highest consistency score at 91.832, underscoring his sustained high performance over his career. He also ranks highly in winningness, just behind Michael Jordan and Kareem Abdul-Jabbar, who both score exceptionally for their individual achievements and leadership. Michael Jordan leads in performance score with a perfect 100, reflecting his dominance during his peak years through his offensive and defensive prowess. Notably, LeBron James, Karl Malone, and Shaquille O'Neal also score high in this category, indicating their significant contributions. The higher standard deviation at the top of the performance rankings suggests greater uncertainty due to limited data for these top performers.

The GOAT Score, blending performance, consistency, longevity, and winningness, positions Michael Jordan as basketball's GOAT with a score of 903.48, closely followed by LeBron James at 893.01. This ranking emphasizes their comprehensive dominance in basketball. Other legends like Karl Malone, David Robinson, and Tim Duncan also appear prominently, reflecting their well-rounded excellence and impact on the sport. This is interesting- while players like Karl Malone may surpass Jordan in consistency, Jordan's superior performance and accolades like MVPs and championships enhance his overall GOAT Score. Players with balanced careers like Tim Duncan and David Robinson, despite not topping individual categories, achieve high GOAT Scores due to their significant overall impact.

# Hockey

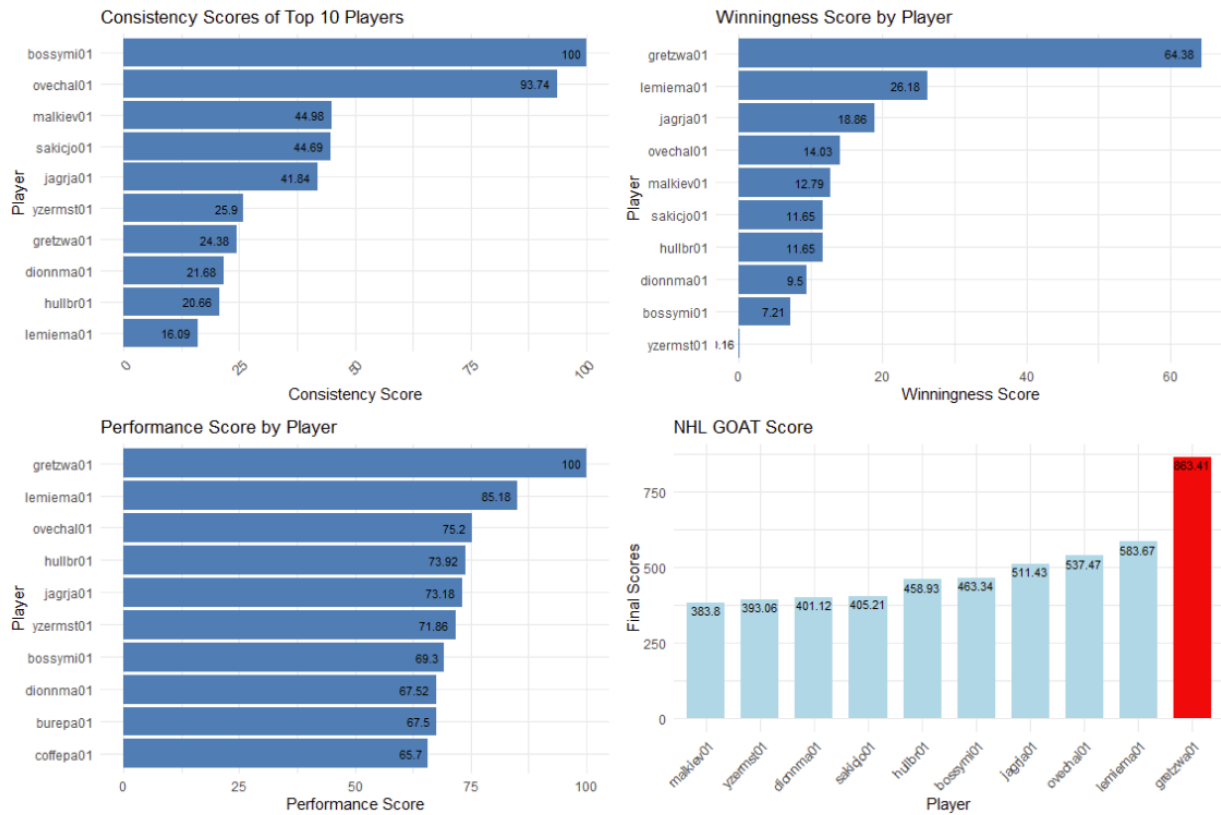


Image 5: Hockey Analysis final plots of overall consistency, winningness, performance, and GOAT Score

In hockey analysis, Wayne Gretzky is the standout player, despite Mike Bossy leading in consistency with a perfect score, followed by Alexander Ovechkin. Gretzky, though not the highest in consistency, still ranks highly. His winningness is highlighted by his 9 Art Ross trophies and 4 Stanley Cups, surpassing other legends like Mario Lemieux and Jaromír Jágř. Gretzky also tops the performance score category with an unmatched 100, reflecting his superior offensive skills and game impact, with Lemieux trailing at 94.2. Despite an average standard deviation of 9 points in performance scores, Gretzky's lower confidence interval at 92.44 still exceeds Lemieux's average.

Wayne Gretzky's final GOAT Score is an impressive 963.41, affirming him as the greatest hockey player of all time. Mario Lemieux ranks second with a score of 583.67, notable for his significant contributions and resilience through health challenges.

# American Football

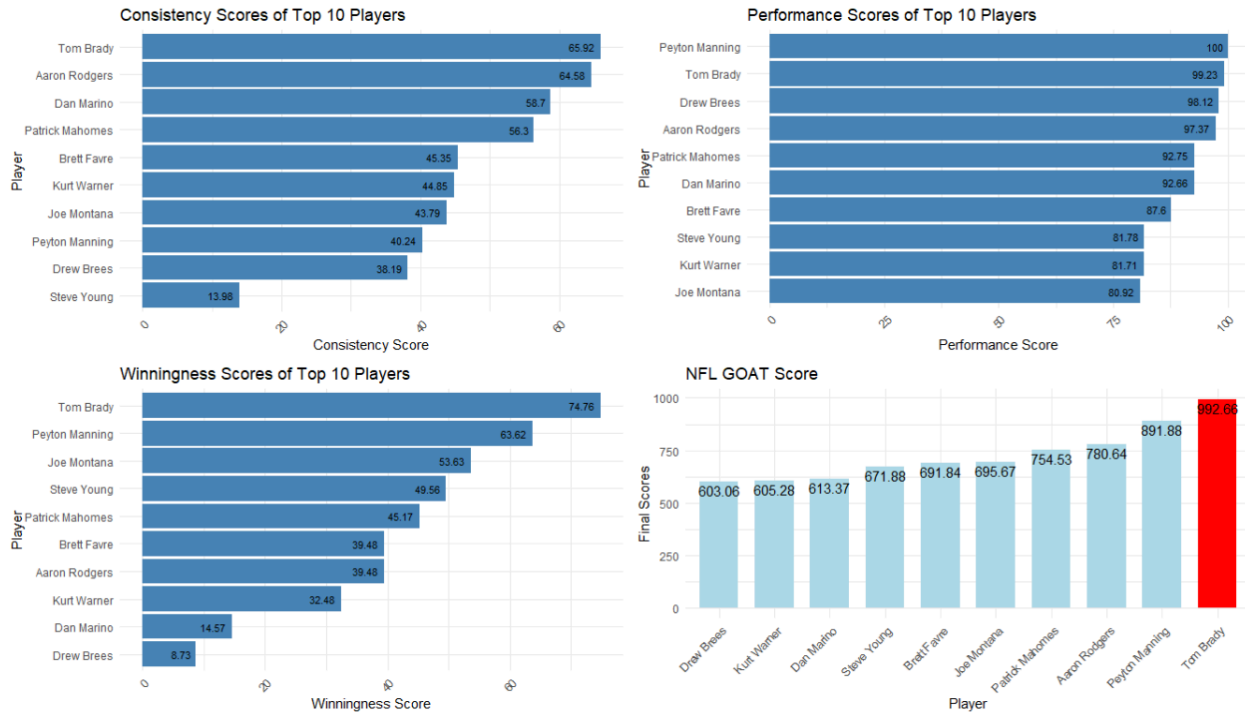


Image 6: Football Analysis final plots of overall consistency, winningness, performance, and GOAT Score

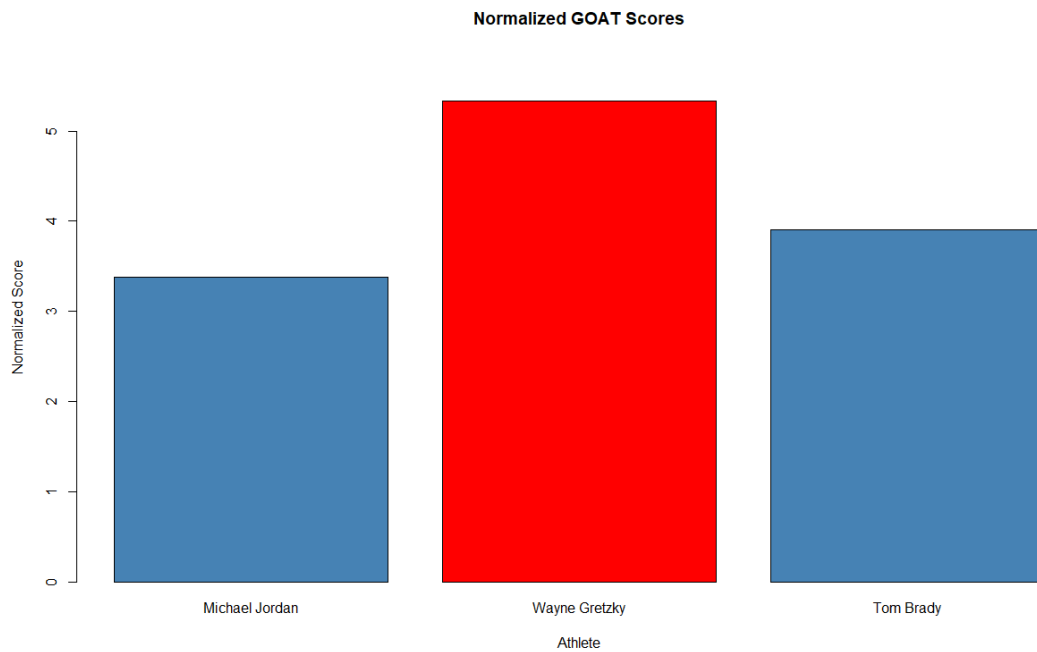
In football analysis, Tom Brady leads with the highest consistency score at 65.52, illustrating his long-term high performance and success in the NFL. Aaron Rodgers and Dan Marino also show strong consistency, indicating reliable performance over their careers.

Tom Brady tops the winningness scores with 74.76, reflecting his ability to lead his teams to numerous victories and titles. Peyton Manning and Joe Montana also score highly, underscoring their impactful careers. Notably, the confidence intervals suggest that Manning’s leading position is not secure, with Brady’s potential score possibly exceeding Manning’s. This highlights a debate over their peak performances, further complicated by a standard deviation of 69 points across player scores, adding to the uncertainty. Despite this, Manning holds the top spot in performance scores, but with considerable uncertainty as Brady presents a strong challenge.

Combining all these aspects into the NFL GOAT Score, Tom Brady is recognized as the greatest quarterback of all time with a score of 992.6, due to his unmatched consistency, strong performance, and winningness. Peyton Manning follows behind at 891.88.



# GOAT of GOATs



*Image 7: Overall Comparison of GOAT Scores*

After normalizing and comparing the GOAT Scores across three sports, Wayne Gretzky emerges as the undisputed greatest of all time, followed by Tom Brady and Michael Jordan. Reflecting on childhood debates, it's notable that while discussions often questioned whether Jordan or Brady was the GOAT, Gretzky was always the clear choice in hockey, unmatched in accomplishments and impact. This consensus extends to Gretzky now being recognized as the ultimate GOAT of the GOATs.

## Discussion

From a broad analysis, it's evident that the GOAT player typically excels in most, if not all, of the criteria used to determine the GOAT score. Interestingly, players not ranked in the top 5 for several metrics often rank higher in the overall GOAT standings than expected, largely due to the calculation method of the GOAT Score. A notable example is Karl Malone, who ranks top 3 in both consistency and performance but is absent from the top 10 in overall GOAT score, primarily because he never won a championship. This significantly impacts his ranking compared to champions like Michael Jordan and LeBron James. This scenario highlights the benefit of a comprehensive GOAT Score, which values consistent performance and development over time.

Our analysis in selecting a GOAT of GOATs was thorough but faced some limitations that affected its conclusiveness. We only analyzed data from 1980 onwards, due to the unavailability of many common stats before this period, excluding legends like Bobby Orr, Wilt Chamberlain, Bill Russell, and Roger Staubach. Furthermore, our focus was solely on team sports, leaving out individual sports legends such as Michael Phelps, Novak Djokovic, and Tiger Woods, whose inclusion could potentially alter the rankings.

The challenge lies in comparing achievements across team and individual sports, as the dynamics differ significantly in terms of individual impact and pressure.

Looking ahead, we aim to include more team sports like baseball, cricket, and soccer, which share similar dynamics and can allow for more generalized comparisons. Despite potential data challenges, expanding our analysis to these sports and considering the level of competition within more popular sports will provide a more rounded assessment, acknowledging the increased competition top athletes face in more widely followed sports.

## Why Sampling and Estimation Doesn't Make Sense

Another major takeaway from this analysis was that sampling and estimation don't make sense for this research question. Given the historical nature of the analysis, many of the statistics, if taken at face value, do not have uncertainty – these are events that have already happened. As such, we had to get creative with how we analyzed the dataset. For example, instead of simply summing up a weighted average of a given player's 5 best seasons to determine performance score, we decided to determine performance score by how much better a player was than the league average over 5 years and take the 5 years where the given player dominated the most. This change in angle gave us an opportunity to use regression analysis and employ the residuals of the model to eliminate biases incurred due to the era that each player played in.

We could have considered other questions that would require more estimation. For example, another potential project could have been determining the metrics or statistics that matter the most to a person given their ranking of GOATs within a sport. With a set ranking, we could have regressed the metrics on the ranking to find the weights of each statistic.

All in all, based on our statistical analysis of the data, Wayne Gretzky is the GOAT of GOATs within basketball, football, and hockey, based on data from 1980 onwards.