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NFL Player Rating Systems: An Investigation of the Passer Rating and Proposal for a Rusher Rating

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Abstract

The passer rating system (PRS) in the National Football League is designed to quantify a quarterback's efficiency across seasons and careers. While many fans are aware of the measure, few truly know how the formula was designed or is calculated. This paper will analyze the already in place PRS, and propose a similar efficiency rating system for the position of running back. The PRS and rusher rating system (RRS) are then analyzed with player data by both season and career. A final addition is a look at adjusted ratings for seasons and careers based upon differences in yearly averages for both rating systems.

Key Words: Player performance ratings, Football rankings, NFL career/season player analysis.

1 Introduction

Beginning in 1932, the National Football League (NFL) has used nine different systems for crowning the best quarterback for a given season. The latest, implemented in 1973, is a rating system using a number of statistics dubbed the "Passer Rating System" (PRS). While there are some flaws and numerous complaints with the PRS, it is the official statistic the NFL has used for over thirty years to rate quarterbacks despite the offering of alternative measures (Berri et al., 2006; Carrol, 1986; Carrol et al., 1988; DeOliveira and Callum, 2004) This paper does not argue for or against the current PRS, but rather investigates each element of the rating system which is currently in use by the league.

Despite its supposed flaws, the NFL has decided to adhere to the PRS. The league has spent countless time and numerous broadcasts familiarizing the public with the PRS. The mass marketing strategy has been a success with the PRS being a statistic regularly presented in NFL game broadcasts, sports highlights and analysis shows, and reports in all formats. Consequently, though the general fan or player most likely can not recite its derivation (Bialik, 2008; Steinberg, 2008), many have an understanding of the scale, particularly values constituting good or bad scores. Switching to a new rating system could jeopardize all the progress that the league has made with this rating system, and thus flawed as it may be, the league is leery to abandon it (Berri, 2007).

Crowning a rushing champion in the NFL, on the other hand, is extremely simplistic. The player with the most rushing yards at the end of a season is given the title of best running back. To our knowledge there has been no development or accepted formula comparable to the PRS for the running back position (although Bysina (1983) proposes a similar formula for the wide receiver position; DeOliveira and Callum (2004) uses a linear programming technique to study quarterback efficiency and extends the analysis to running backs). Such a Rusher Rating System (RRS) not only presents a more complete evaluation of running back performance beyond merely rushing yards, but allows for comparisons between positions, namely quarterbacks and running backs. Though we show that in fact the rating systems are comparable over seasons, we find that career rankings based on PRS and RRS favor new era players. We therefore propose rating systems via season adjusted scores to

evaluate player performance relative to his peers.

The paper unfolds as follows. In Section 2 we first briefly detail the PRS as a precursor to the development of the RRS, exposited in an analogous manner in Section 3. Again, our purpose is to create an efficiency rating for running backs along the lines of the NFL approved PRS. Nonetheless, we additionally discuss flaws, popular misconceptions, and avenues for improvement to consider in future research based on analyses particularly of the individual elements of the PRS and RRS. In Section 4 we present and compare the best season and career performances for quarterbacks and running backs via the PRS and RRS. We also detail the proposed adjusted rating score (ARS), displaying a fairer comparison of players across eras. Section 5 is a brief concluding discussion of our thoughts on these rating systems including a comparison of rushing title winners using the RRS as opposed to the current NFL standard of total rushing yards. NFL data was obtained from free online databases at `nfl.com` and `pro-football-reference.com`. During 1960-1970 AFL and NFL data was combined for each season.

2 Quarterbacks

Prior to the PRS, from 1962-1972, the method used to determine passer ratings was based on an inverse ranking system using: percentage of completions, total touchdown passes (except 1972 where total touchdowns was replaced by the percentage of touchdowns), percentage of interceptions, and average gain per attempt (see HOF, 2008, for earlier methods). Each player was ranked in each category and the player with the lowest total score for all categories was the winner. Ordinal rankings of this kind, though, do not contain full information on a player's performance. Most notably, then, it is impossible to compare players across different seasons. For example, due to the changing performances of others, a quarterback who finished first in one year might finish in the middle of the pack in another year with the exact same statistics.

A committee led by Don R. Smith of the Pro Football Hall of Fame, was assigned by commissioner Pete Rozelle to address the problem. The group studied statistics going back to 1960 and eventually arrived at the current PRS. The plan was to abandon the methodology of comparing passers to each other,

and instead use a standard scale against which to compare all quarterbacks. Using the same four statistics as the 1972 method, each quarterback would be judged against historical standards in each element. We first will define the PRS and then in the following subsections discuss each element in turn.

2.1 The Passer Rating

The PRS consists of four separate elements: completion percentage (QC), yards per attempt (QY), touchdowns per attempt (QT), and interceptions per attempt (QI). Each quarterback receives a value from 0 to 2.375 in each element. The basic premise is that each quarterback is compared to the *average* quarterback in each element. The averages for each element were based upon quarterbacks' data from 1960 to the early 1970s. Average scores were designed with a three-point scale in mind: zero for a horrible performance, one for an average performance, and two for a record setting performance. A maximum of 2.375 was placed on each element to allow for future record setting performances, but at the same time to cap one element from dominating the other three elements. The total score is then an equally weighted summation across the four categories followed by a multiplicative factor of 100/6 to place better performances around a value of 100. For example, the designed mean score for quarterbacks, performing at an average score of one in each element, would result in a $4 \times 100/6 = 66.67$ rating. Performing at a score of two in all elements would result in a rating of $8 \times 100/6 = 133.33$. Since each element is capped at 2.375, a perfect rating would be $2.375 \times 4 \times 100/6 = 158.33$. Table 1 lists the criteria needed in each category to receive a given score. Keep in mind that the PRS is an efficiency rating only: it is not a measure of overall total performance, only how a player performed during their chances, regardless of total attempts.

The formulas for each element are as follows:

$$\begin{aligned} QC &= \frac{\frac{\text{Completions}}{\text{Pass Attempts}} \times 100 - 30}{20} \\ QY &= \frac{\frac{\text{Yards}}{\text{Pass Attempts}} - 3}{4} \\ QT &= \frac{\text{Passing Touchdowns}}{\text{Pass Attempts}} \times 20 \\ QI &= 2.375 - \frac{\text{Interceptions}}{\text{Pass Attempts}} \times 25 \ . \end{aligned} \tag{1}$$

The final PRS formula combining the elements is then

$$\text{Passer Rating} = (QC + QY + QT + QI) \times 100/6,$$

$$\text{where } 0 \leq QC,\ QY,\ QT,\ QI \leq 2.375.$$

In the following subsections, we will break down each element and corresponding formula in turn.

Score	0	1	2	2.375
Completion percentage - QC	30%	50%	70%	77.5%
Yards per attempt - QY	3	7	11	12.5
TDs per attempt - QT	0	1/20.0	1/10	1/8.4
INT per attempt - QI	1/10.5	1/18.2	1/66.6	0

Table 1: Statistics required in each PRS element to received a score of 0, 1, 2, or 2.375.

2.2 QC: Completion Percentage

During the early 1970s the average completion percentage was a little over 50%. Therefore, this value was used to correspond to a value of 1 in QC. The record setting performance at the time was 70.33% (Sammy Baugh, 1945), thus 70% was taken as the outstanding performance and assigned a value of 2. A simple linear equation is formed to connect the points $(0.50, 0)$ and $(0.70, 1)$ resulting

in the QC element formula in (1). A major flaw of the passer rating is exposed here as quarterbacks have drastically increased their completion percentages as a whole over the years. In fact, the completion percentage for the league in the 2007 season was 62%, an almost record setting performance compared to 1970. Due to changes in the rules and coaching strategies, many critics argue that these standards need to be updated. Note: League numbers are computed by summing over all qualifying (minimum 14 attempts per game) quarterbacks.

2.3 QY: Yards per attempt

This element is computed using total passing yards divided by total attempts (whether the passes were completed or not). The average yards per attempt for quarterbacks from 1960 to 1973 was close to seven yards per attempt, making this the average value of one in QY. These levels have remained fairly constant over the years, the 2007 league value being 7.05 yards per attempt. The record of 11.17 yards per attempt in 1957 by Tommy O'Connell probably served as the record setting performance although he only had 110 attempts that season. Of note, in 1942 Sid Luckman averaged 10.86 yards per attempt with 202 attempts. Eleven yards per attempt was taken to be the amount needed to receive a value of 2 in QY. Fitting a line to the points $(7, 1)$ and $(11, 2)$ gives the QY element formula in (1).

2.4 QT: Touchdowns per attempt

This element is the ratio of touchdowns a quarterback throws over total pass attempts (whether the passes were completed or not). Rushing touchdowns are not counted in this element. The average for quarterbacks during the years the committee investigated was taken to be a rate of 0.05 or 1 touchdown for every 20 attempts. A great performance, receiving a score of 2, is designated to be a ratio of 0.10 or passing for a touchdown per every 10 attempts. The actual record setting performance at the time was (and still is) Sid Luckman's 1943 season where he scored 28 touchdowns on 208 attempts or a touchdown rate of 1 every 7.2 passes (0.14 ratio). However since the PRS creation committee looked at data going back only to 1960, they most likely used George Blanda's

1961 performance of 1 touchdown per 9.94 attempts as a benchmark for the record setting performance. The linear equation which fits the points $(1/20, 1)$ and $(1/10, 2)$ is simply a multiplicative factor of 20, as seen in the QT element formula in (1). The mean for the 2007 season was 0.044 or a touchdown every 22 passes, consistent with the assumed average quarterback in the rating.

2.5 QI: Interceptions per attempt

This element is the ratio of passes that end up being intercepted out of total passes attempted. This is the only negative category in that the quarterback wishes to minimize his interceptions, thus requiring a somewhat different formulation. Perfect scores (no interceptions) must equate to the value 2.375, so the formula subtracts some function of the the interception rate from this value. The average interception rate was taken to be 0.055, or throwing an interception every 18.2 attempts. The record performance over the time period the committee looked at was Bart Starr's 1966 season where he threw 3 interceptions in 251 attempts for a rate of 0.012. However the record performance was instead taken as a close value of 0.015. The linear equation fitting the points $(0.055, 1)$ and $(0.015, 2)$ subtracted from the value 2.375, gives a multiplicative factor of 25, as seen in the QI element formula in (1).

2.6 Comments and Criticisms

Clear omissions to the PRS are sacks, fumbles, and rushing statistics. However, while these are all important to the game and can occur on any given passing play, none are a true measure of passing efficiency. Sacks and fumbles prevent the quarterback from actually passing the ball. Rushing statistics are accumulated from rushing plays (or broken passing plays). Sacks, fumbles, and rushing statistics are all extremely important factors when determining a quarterback's overall contribution to a team, but when evaluating strictly passing efficiency these factors are correctly omitted. The PRS is solely a measure of how well a quarterback does when he puts the ball in the air.

Due to rule changes and offensive strategies, quarterbacks over the past few years, on average, have thrown for a much higher completion percentage and a much lower interception rate than their 1970 average counterparts. Inter-

estingly QY and QT have remained fairly constant. Figure 1 shows that the league score (sum of all qualifying quarterbacks) in each element and passer rating have changed over time since 1950. It is clear that the term *average* is relative to the time period. Quarterbacks scoring below average in 2007 are still scoring higher than many of the superstars of the 1970s and 1980s. Although the PRS was designed to compare players across years, it is an interesting debate on whether a player from 2007 can be directly compared to one from 1970 with such a clear discrepancy in averages.

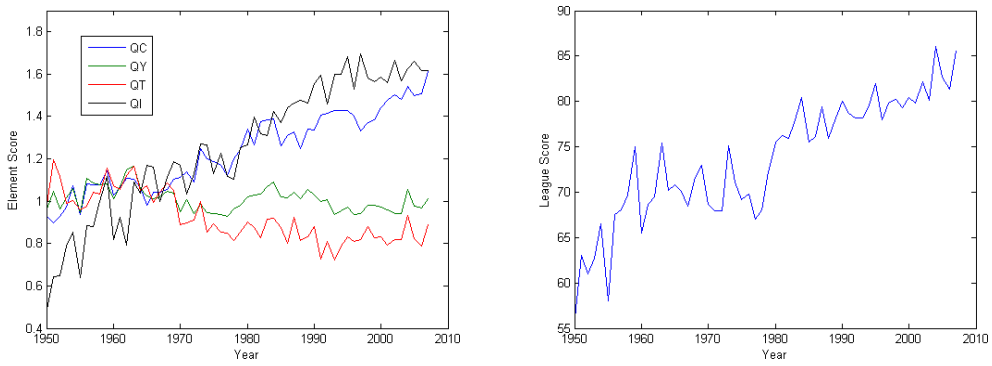

Figure 1: League passer rating scores over time. The plot on left breaks down scores by element and the plot on right presents league passer ratings scores.

Table 2 shows the percentiles of all quarterback data in each element since 1950. Overall, the final passer rating scores seem to align with what the originators intended. However, notice that not all elements are equally distributed. The variance in QY is much smaller than that in QI. Solely comparing QY, and QI, suppose a quarterback had an option of scoring excellent (99th percentile) in one element and horrible (1st percentile) in the other. Due to the difference in variance he would optimize his combined score (2.355 vs. 1.742) by performing excellent in QI, by not throwing any interceptions, but score horribly in QY for throwing for very low yards per attempt. While this is a highly trivial example, the pattern of shorter, safer throws as opposed to deep passes down the field has been a continuing trend over the past few decades. However, keep in mind these percentiles are calculated over 57 seasons and have not remained constant on a year by year basis (Figure 1) so a direct

calculation of each element's importance from these percentiles is not a valid measure.

Percentile	QC	QY	QT	QI	Passer Rating
1	0.552	0.515	0.320	0.040	39.93
5	0.785	0.656	0.444	0.572	50.96
10	0.900	0.730	0.530	0.771	56.39
25	1.085	0.852	0.670	1.064	65.82
50	1.283	0.990	0.855	1.392	75.16
75	1.461	1.134	1.070	1.640	84.00
90	1.615	1.248	1.296	1.798	91.40
95	1.707	1.373	1.434	1.900	96.23
99	1.889	1.544	1.702	2.035	104.74
sd	0.248	0.195	0.273	0.327	12.75

Table 2: Percentiles in the passer rating elements for all qualifying players (1950-2007; $n = 1522$), with the last row presenting the standard deviation for each element.

An additional flaw with the PRS is that yards receivers gain after a completion (yards after the catch, YAC) count toward a quarterback's numbers. Using a statistic like air yards or total YAC for a quarterback subtracted from total passing yards is an easy remedy to this element's formulation.

In *The Hidden Game of Football* (Carrol et al., 1988), which presents a comprehensive history of the development of the PRS, the authors criticize the rating for capping horrible, and more importantly, superb performances. Additional criticisms include that completion percentage (QC) should be removed and touchdowns QT and interceptions QI are both weighted too heavily. They propose a new statistic, primarily through a reweighting of the four elements of PRS. However, their rating system has not been adopted by the NFL. As our purpose herein is to exposit a running back rating system analogous to the NFL PRS, we leave discussion of alternative and improved PRS formulations, a whole topic in and amongst itself, to future work.

3 Running Backs

Determining the rushing champion in the NFL is much more simplistic than the PRS used to analyze quarterbacks. Total rushing yards is the only statistic used and whoever has the most at the end of the season is determined to be the winner. Although the league determined that passing yards alone was insufficient to rate quarterbacks in 1938, running backs continue to be evaluated only by a simple total. To our knowledge there has been no development or accepted formula comparable to the PRS for the running back position. We will now propose the general formula followed by a detailed explanation of each element.

3.1 The Rusher Rating

When designing an analogous efficiency system for running backs, the first step is the selection of statistics to use. Keeping in line with the four elements of the passer rating formula outlined in Section 2, the statistics we will use to evaluate a running back's efficiency are: yards per reception in combination with receptions per game (RC), yards per rush (RY), touchdowns per attempt (RT), and fumbles per attempt (RF). Note that total attempts is the combined total of receptions and rushes; fumbles are classified as the total of both recovered and unrecovered fumbles.

The basic premise of the formula will be kept in line with the passer rating where in each element an average performance scores a one, an absolutely outstanding performance scores a two, and a horrible performance scores a zero. Each element is bounded between 0 and 2.375 as in the PRS. However, the derivation of the element formulas will be done slightly differently. Pegging the scores of a 2 in each element using previous records from 1960-1973 is not a valid baseline for two reasons. First, some running backs stand out as extreme outliers in each category and using these performances as the only measure of greatness is not fair. Secondly, the statistics used to calculate each element change rapidly through the years. Therefore we will use top percentiles (93-99) from the 2481 qualifying running back seasons from 1950-2007 as the measure of greatness for the derivation of the element formulas. For consistency with the PRS, any element which has performance levels changing

over time will have the corresponding formula fit using percentiles from the same time period used to calculate the formulas of the PRS in (1). Note: A qualifying running back season is one where the players averaged 6.25 carries or more per scheduled game (100 carries per 16 game season). All percentile calculations are from these 2481 qualifying seasons.

The formulas used to calculate the rusher rating are as follows:

$$\begin{aligned} RC &= (RC_1 + RC_2)/2 \\ RC_1 &= \left(\frac{\text{Yards Receiving}}{\text{Receptions}} - 4\right) \times \frac{1}{5} \\ RC_2 &= \sqrt{\frac{\text{Receptions}}{\text{Games Played}}} - 0.4 \\ RY &= \left[\left(2 \times \frac{\text{Rushing Yards}}{\text{Rush Attempts}}\right) - 5\right] \times \frac{1}{3} \\ RT &= \frac{\text{Touchdowns}}{\text{Total Attempts}} \times 35 \\ RF &= 2.375 - \left(55 \times \frac{\text{Fumbles}}{\text{Total Attempts}}\right) \end{aligned} \tag{2}$$

$$\text{Total Attempts} = \text{Total Receptions} + \text{Total Rush Attempts.}$$

The final RRS formula combining the elements is then

$$\text{Rusher Rating} = (RC + RY + RT + RF) \times 100/6$$

$$\text{where } 0 \leq\ RC_1,\ RC_2,\ RY,\ RT,\ RF \leq 2.375.$$

Analogous to Table 1, Table 3 shows the statistics needed for each level of scoring in each element.

3.2 Yards per reception: *RC*

This element rates running back performances in the passing game through two different measures: yards per reception and receptions per game. The

Score	0	1	2	2.375
Yards per reception - RC_1	4	9	14	15.875
Receptions per game - RC_2	0.2	2	5.8	7.7
Yards per rush - RY	2.5	4	5.5	6.063
TDs per attempt - RT	0	1/35	2/35	1/14.7
Fumbles per attempt - RF	1/23.2	1/40	1/146.7	0

Table 3: Statistics required in each running back rating element to received a score of 0, 1, 2, or 2.375.

inclusion of receptions per game addresses the volatility in this category from players with a small number of receptions.

The average yards per reception, RC_1, was 8.9 for all qualifying running back seasons. An outstanding performance was taken to be 14 yards per reception being at the 94th percentile. Fitting a line to the points $(9, 1)$ and $(14, 2)$ results in the RC_1 element formula in (2).

RC_2 is a measure using receptions per game. The distribution of receptions per game is highly positively skewed, thus the application of a square root transformation. The mean and median of the transformed distribution from all qualifying running backs from 1950-2007 were both 1.34. Following the same guidelines in the PRS, to align this with the desired average near 1, 0.4 is subtracted from the total.

The average of RC_1 and RC_2 is taken as the final measure of a running back's efficiency in the passing game. Both RC_1 and RC_2 are bounded between 0 and 2.375 before the average is calculated, preventing one element from dominating the other. There are a number of different combinations of RC_1 and RC_2 players can have which may result in the same RC score. As seen in Table 4 this category has a smaller variance than other elements. This is due to the fact that it is very difficult for a player to simultaneously have a large number of receptions per game and a large average gain.

3.3 Yards per rush: RY

Four yards per rush is the average and median value corresponding to a value of one. The 98th percentile is at 5.5 yards per carry. This category has

been fairly consistent over the years so no adjustments were needed. A linear equation fit to the points $(4, 1)$ and $(5.5, 2)$ gives the RY element formula in (2).

3.4 Touchdowns per attempt: RT

Disappointingly, no records for this statistic are calculated by the NFL for public consumption. For example, only total rushing and receiving touchdowns are listed at `nfl.com`. Converting to a rate using total attempts, the average and median were 0.0305 (1/32.8) and 0.0280 (1/35.8) respectively. There is a slight positive skew to the distribution of all the rates, thus using the median would give a better measure of center. The rate used to assign an average score of one was taken to be 1 touchdown per 35 attempts or a rate of 0.0286. Due to the positive skew, there is a large amount of variability around the top percentiles. The 90th percentile is 0.0526 (1/19) whereas the 99th percentile is 0.0801 (1/12.4). Scoring a touchdown every 19 or 12.4 attempts is a significant difference when trying to decide the measurement of success. To be conservative, and given the nature of a multiplicative formula analogous to QT, the choice was made to use the 93rd percentile and a touchdown rate for excellence being 1 per 17.5 attempts or 0.0571, half that of the average. A linear equation is then fit to $(1/35, 1)$ and $(2/35, 2)$ resulting in the RT element formula in (2).

3.5 Fumbles per attempt: RF

This element is plagued by multiple factors. First, fumble rates have drastically changed over the past sixty years, with modern day running backs fumbling far fewer times than their older counterparts. Second, many running backs have very low fumble counts during a given season; some running backs might not have even a single fumble. Therefore to account for the performance bias as eluded to in the QC and QI elements of PRS, the RF element will also be fit to the time period used to formulate the PRS to ensure running backs of that era attain an average value of one, but more recent running backs will score higher on average due to their improved fumble rates. From 1960-1972 the median and mean fumble rates from qualifying running backs was 0.0227

(1/44) and 0.0248 (1/40.3) respectively.

Like QI, it is the only negative category and must employ a different type of formula than the other elements. An equation using a similar strategy to fit QI was used for the point $(0.025, 1)$. The constant 55 is multiplied by the fumble rate, which when subtracted from 2.375 will give the correct value. The other data points in Table 3 needed to score a two or zero both make sense as well.

3.6 Comments and Criticisms

Figure 2 shows that three of the four elements, RY, RT, and RC, have remained relatively constant over the years, but RF has seen a drastic increase all the way from 0.2 in 1950 to 1.8 in 2007. The fact that the league running back efficiency score has increased so dramatically since 1980 can almost be completely attributable to the reduction in fumble rates.

Despite the volatility of RF, the proposed RRS appears to be able to effectively grade the efficiency of running backs as a whole. Most elements that involve a running back are included in the RRS. Omissions include blocking ability, possible special teams plays, and passing statistics. However, since blocking ability is a hard statistic to quantify due to lack of data, and most starting running backs do not play special teams or pass the ball that often (if at all) we see no reason to include these statistics in the RRS.

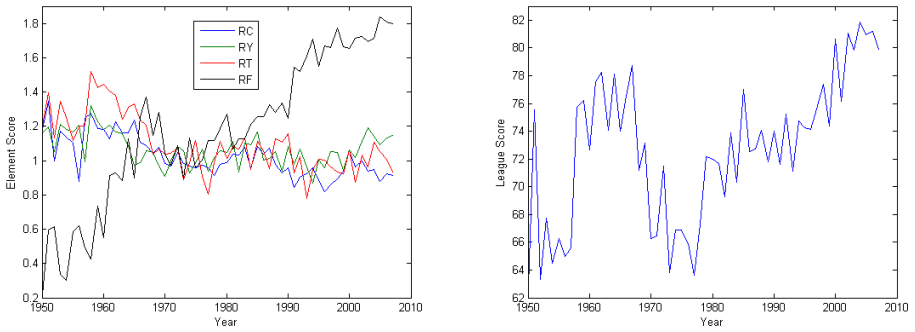

Figure 2: League rusher rating scores over time. Plot on left breaks down scores by element. Plot on right presents league rusher rating scores.

Percentile	RC	RY	RT	RF	Rusher Rating
1	0.120	0.123	0.000	-1.446	30.80
5	0.369	0.395	0.257	-0.352	41.17
10	0.498	0.526	0.402	0.164	48.91
25	0.735	0.739	0.655	0.787	60.07
50	0.961	0.986	0.979	1.337	71.27
75	1.188	1.283	1.388	1.767	83.14
90	1.394	1.570	1.842	2.053	93.74
95	1.525	1.807	2.203	2.230	101.36
99	1.747	2.304	2.831	2.375	115.19
sd	0.348	0.437	0.597	0.812	17.80

Table 4: Percentiles in the rusher rating elements for all qualifying players (1950-2007; n=2481). Note scores below zero or above 2.375 are capped for the final rating.

Even though both the passer rating and rushing rating have increased since the 1950s, Figure 3 shows that the rate for each is fairly similar across positions. Thus, while the rating system might have some bias comparing players of today to older generations, players in a given season may be compared across positions.

4 Player Ratings

Studying the scores on a player by player basis reveals some interesting results. We will first look at some of the best season performances, then the best careers, and finally career adjusted scores.

4.1 Scores By Season

Table 5 presents the top ten seasons for passer and rusher ratings. Note that the top rusher ratings are slightly higher than the top ten passer ratings despite the recent slightly lower league scores seen in Figure 3. Overall, both systems seem to be able to identify outstanding seasons, as each performance on the list is surely an outstanding season. For example, in 2004 Peyton Manning passed

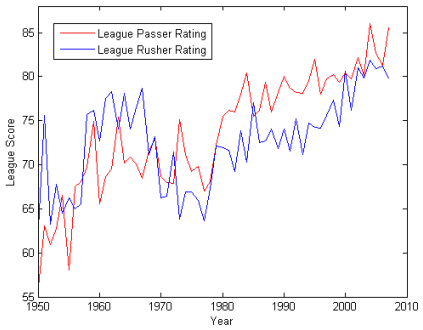

Figure 3: Yearly league rating for quarterbacks and running backs 1950-2007

for 4,557 yards with a 67.6% completion percentage, with 49 touchdowns and 10 interceptions. However, in 2000 Marshall Faulk had an even better season (by comparing ratings), where he rushed for 1,359 yards on only 253 carries (5.4 average), caught 81 passes for 830 yards (10.2 average), and scored 26 touchdowns, without fumbling even once.

These ratings are very much in line with those presented by the Football Outsiders group who are currently considered to be on the cutting edge of football statistics. On a list of the top twenty seasons from 1995-2007, according to their play-by-play metric of total DYAR (Schatz, 2008), the top 6 seasons that qualify from their list all appear in Table 5 as well. Interestingly then, simpler summaries based on yearly statistics may be sufficient to, at the least, rank the top season performances.

4.2 Scores by Career

As expected, Table 6 shows that efficiency ratings for the top players over their entire careers are somewhat lower than that for a season. In order to qualify for the table, a quarterback must have at least 1500 career attempts, whereas a running back must have a minimum of 750 career carries. At a rating of 108.7, Lenny Moore clearly stands out. He was used frequently as a wide receiver in addition to a running back (25% of his total attempts were receptions) thus skewing his rusher rating. To classify him as purely a running back, we believe, would be erroneous, though he did have over 1000 carries in

Quarterbacks			Running Backs		
Name	Season	PR	Name	Season	RR
1. Peyton Manning	2004	121.1	1. Marshall Faulk	2000	138.2
2. Tom Brady	2007	117.2	2. Leroy Kelly	1966	129.1
3. Steve Young	1994	112.8	3. Priest Holmes	2002	127.9
4. Joe Montana	1989	112.4	4. LaDainian Tomlinson	2006	125.5
5. Daunte Culpepper	2004	110.9	5. Marshall Faulk	2001	124.2
6. Milt Plum	1960	110.4	6. Priest Holmes	2003	121.8
7. Kurt Warner	1999	109.2	7. O.J. Simpson	1975	119.9
8. Dan Marino	1984	108.9	8. Abner Haynes	1962	118.4
9. Steve Young	1992	107.0	9. Marshall Faulk	1999	117.2
10. Randall Cunningham	1998	106.0	10. Mercury Morris	1973	115.2

Table 5: Top ten ratings for single season 1950-2007. Minimum qualifications: average of 14 att/game for QBs; 62.5 avg yards per scheduled game and 6.25 carries/scheduled game (1000 yards rushing and 100 carries in any 16 game season) for RBs.

his career and was extremely efficient in all aspects of the game. Both lists favor new era players, when the league passer and rusher ratings average is much higher. This leads us into the next section which adjusts for the time period played.

4.3 Era Adjusted Scores

Since there is a clear progression of average scores in both the PRS and RRS (Figure 3), comparisons of players across years is difficult to interpret. Is a score of 80 in 1955 really worse than an 83 in 2007? Probably not.

This section abandons the initial goal of the PRS where players would be compared to set standards. Instead, a normalization performed on a year by year basis will compare players to one another. Thus a rating here is highly dependent on other players' performances whereas in the original PRS and RRS, scores are based upon fixed historical standards independent of current performances. One possibility would be to just subtract the mean of each year from each player's score. However, this assumes that there is equal variance for each year. A Bartlett's test on the years 1950-2007 shows this supposition may be erroneous (p-value ≤ 0.001 for both PRS and RRS), so we will use the

Quarterbacks		Running Backs	
Name	PR	Name	RR
1. Steve Young	96.8	1. Lenny Moore	108.7
2. Peyton Manning*	94.7	2. Larry Johnson*	102.3
3. Kurt Warner*	93.2	3. Priest Holmes	101.2
4. Tom Brady*	92.9	4. Brian Westbrook*	101.2
5. Joe Montana	92.3	5. LaDainian Tomlinson*	99.9
6. Carson Palmer*	90.1	6. Jim Brown	96.2
7. Daunte Culpepper*	89.9	7. Marshall Faulk	95.1
8. Chad Pennington*	88.9	8. Barry Sanders	91.3
9. Marc Bulger*	88.1	9. Clinton Portis*	88.6
10. Drew Brees*	87.9	10. Terrell Davis	88.5

Table 6: Top ten career ratings for careers beginning in 1950 or later. (Minimum 1500 pass attempts, 750 carries). *Denotes an active player.

variance of the scores from each year in the normalization.

The methodology for standardizing will be as follows. For year i, let x_i denote the player score with $\bar{x}$ and s denoting the weighted mean and weighted standard deviation of the scores, where the weights are the ratio of total attempts for each qualifying player to the league total in year i. The adjusted rating score (ARS) is then

$$\text{ARS} = \sum_i \left(\frac{\text{Total Attempts}_i}{\text{Total Career Attempts}} \times z_i \right),$$

where $z_i = (x_i - \bar{x}_i)/s_i$, is the normalized score for a player for year i. Each z_i is calculated using a mean and variance weighted by plays attempted. For example, in the calculation of $\bar{x}_i$, the average of two passer ratings of 95.0 and 85.0, one from a quarterback with 200 attempts and another from a quarterback with 450 attempts, should not simply be an average passer rating of 90.0. Therefore $\bar{x}$ and s are yearly calculations weighted by each player's total attempts.

Similarly, for an individual player, a rating of 92.0, in which only 50 passes were attempted in his rookie season say, cannot be averaged with equal weights

against his best rated season of 98.0 with over 500 attempts. We thus weight each players z_i's according to individual attempts made in season i.

Quarterbacks				Running Backs			
Name	Year	ARS	PR	Name	Year	ARS	RR
1. Joe Montana	1989	3.248	112.4	1. Marshall Faulk	2000	3.631	138.2
2. Steve Young	1994	3.243	112.8	2. Marshall Faulk	2001	3.185	124.2
3. Milt Plum	1960	3.162	110.4	3. Mercury Morris	1973	3.079	115.2
4. Kurt Warner	1999	2.756	109.2	4. Marshall Faulk	1999	2.811	117.2
5. Otto Graham	1955	2.687	94.0	5. O.J. Simpson	1975	2.809	119.9
6. Peyton Manning	2004	2.636	121.1	6. Priest Holmes	2002	2.695	127.9
7. Tom Brady	2007	2.596	117.2	7. Leroy Kelly	1968	2.541	109.5
8. Roger Staubach	1971	2.572	104.8	8. LaDainian Tomlinson	2006	2.460	125.5
9. Steve Young	1997	2.558	104.7	9. Barry Sanders	1997	2.454	111.3
10. Steve Young	1992	2.443	107.0	10. James Brooks	1986	2.409	110.4

Table 7: Top ten adjusted ratings for single season, 1950-2007. Minimum qualifications: 14 att/game for QBs; 62.5 avg yards/scheduled game and 6.25 carries/scheduled game for RBs.

Analogous to Table 5, Table 7 presents the top ten rated quarterbacks and running backs based on ARS. For comparison purposes, Table 7 also presents the player rating system scores. Comparing Tables 5 and 7 we see some changes in the overall season rankings, but in general the same top performances remain at the top.

Notice that Table 8 looks more like a typical ranking of the best players of all time (Sando, 2008; Yasinskas, 2008). This gives credence to the theory that players' careers can be compared across eras by normalizing performances based upon the level of their peers. However, this does not mean that Steve Young is definitely the most efficient quarterback of all time. Recall a player's ARS is dependent on other players' performances, both good and bad. In the 1950s and 1960s there were a few extremely good players but also some extremely bad performing players. Including these poor performances increases the variance in a given year and thus hurts the best players' ARS.

5 Discussion

Comparing the rushing title winners to season winners of the RRS, see Table 9, shows that only in 21 of the past 56 years (37.5%) (removing strike years) the

Quarterbacks		Running Backs	
Name	ARS	Name	ARS
1. Steve Young	1.633	1. Larry Johnson*	1.378
2. Joe Montana	1.312	2. Priest Holmes	1.355
3. Peyton Manning*	1.184	3. Brian Westbrook*	1.339
4. Roger Staubach	1.116	4. Lenny Moore	1.248
5. Kurt Warner*	1.056	5. Marshall Faulk	1.166
6. Tom Brady*	0.916	6. Barry Sanders	1.154
7. Sonny Jurgensen	0.866	7. LaDainian Tomlinson*	1.119
8. Len Dawson	0.809	8. Jim Brown	1.054
9. Fran Tarkenton	0.748	9. Leeroy Kelly	0.967
10. Ken Anderson	0.727	10. Terrell Davis	0.854

Table 8: Top ten career adjusted ratings (Min:1500 pass 750 carries) for careers beginning in 1950 and later. *Denotes Active Player.

title holder agrees. The average rusher rating score for players who have won the rushing title is a very good 89.1 , but the average of the highest rusher ratings for those 56 seasons is an exceptional 102.8.

In 1937 the NFL moved away from determining the passing leaders by total passing yardage, eventually arriving at the current PRS in 1973. While there are some flaws with the PRS, it is and probably will continue to be the primary efficiency rating system used by the NFL. However, over seventy years later the league still uses this same philosophy for determining the rushing title, naming whichever player rushes for the most yards the champion. The league has toiled with finding a system to rate quarterbacks for decades, but never proposed an analogous method for running backs. The RRS proposed is an analogous system which does well in identifying the most efficient seasons and careers for running backs. Instead of looking only at total rushing yardage, the RRS can better determine which player is playing at a high level over a season or career. If the league is comfortable using a formula like the PRS to determine the passing champion then we see no reason not to adopt a similar system for the position of running back.

Table 9: Rushing Title Winners vs. RRS winners. Qualifiers for RR winner are a minimum of 62.5 yards per scheduled game (1000 yards per 16 games) and minimum 100 carries. * Removed from average due to strike that year.

	Rushing Title Winner			Rusher Rating Winner		
Year	Name	Yds	RR	Name	Yds	RR
2007	LaDainian Tomlinson	1474	111.1	Adrian Peterson	1341	112.9
2006	**LaDainian Tomlinson**	1815	125.5	**LaDainian Tomlinson**	1815	125.5
2005	Shaun Alexander	1880	102.7	Larry Johnson	1750	109.7
2004	Curtis Martin	1697	91.3	Tiki Barber	1518	98.9
2003	Jamal Lewis	2066	86.9	Priest Holmes	1420	121.8
2002	Ricky Williams	1853	90.9	Priest Holmes	1615	127.9
2001	Priest Holmes	1555	93.1	Marshall Faulk	1382	124.2
2000	Edgerrin James	1709	96.3	Marshall Faulk	1359	138.2
1999	Edgerrin James	1553	86.7	Marshall Faulk	1381	117.2
1998	**Terrell Davis**	2008	111.4	**Terrell Davis**	2008	111.4
1997	**Barry Sanders**	2053	111.3	**Barry Sanders**	2053	111.3
1996	Barry Sanders	1553	86.7	Terry Allen	1353	89.7
1995	**Emmitt Smith**	1773	99.1	**Emmitt Smith**	1773	99.1
1994	**Barry Sanders**	1883	102.0	**Barry Sanders**	1883	102.0
1993	**Emmitt Smith**	1486	95.4	**Emmitt Smith**	1486	95.4
1992	Emmitt Smith	1713	95.5	Ricky Watters	1013	105.2
1991	Emmitt Smith	1563	73.3	Thurman Thomas	1407	96.9
1990	**Barry Sanders**	1304	112.8	**Barry Sanders**	1304	112.8
1989	Christian Okoye	1480	58.7	Neal Anderson	1275	95.6
1988	Eric Dickerson	1659	89.1	Ickey Woods	1066	91.8
1987*	Charles White	1374	65.4	Herschel Walker	891	91.4
1986	Eric Dickerson	1821	65.0	James Brooks	1087	110.4
1985	Marcus Allen	1759	96.2	Roger Craig	1050	108.3
1984	Eric Dickerson	2105	72.4	Marcus Allen	1168	94.7
1983	Eric Dickerson	1808	80.8	William Andrews	1567	90.0
1982*	Freeman McNeil	786	76.3	William Andrews	573	103.1
1981	George Rogers	1674	61.5	Billy Sims	1437	95.5
1980	**Earl Campbell**	1934	83.9	**Earl Campbell**	1934	83.9
1979	Earl Campbell	1697	80.9	Mike Pruitt	1294	87.7
1978	Earl Campbell	1450	67.2	Walter Payton	1395	83.9
1977	**Walter Payton**	1852	88.6	**Walter Payton**	1852	90.3
1976	**O.J. Simpson**	1503	88.7	**O.J. Simpson**	1503	88.7
1975	**O.J. Simpson**	1817	119.9	**O.J. Simpson**	1817	119.9
1974	Otis Armstrong	1407	97.7	Don Woods	1162	101.9
1973	O.J. Simpson	2003	95.5	Mercury Morris	954	115.2
1972	O.J. Simpson	1251	61.2	John Riggins	944	94.2
1971	Floyd Little	1133	73.3	Larry Csonka	1051	106.6
1970	Larry Jr. Brown	1125	78.8	MacAurthur Lane	977	110.3
1968	Gale Sayers	1032	64.0	Tom Matte	909	93.4
1968	**Leroy Kelly**	1239	109.5	**Leroy Kelly**	1239	109.5
1967	Jim Nance	1458	61.9	Hoyle Granger	1194	102.8
1966	Jim Nance	1458	83.7	Leroy Kelly	1141	129.1
1965	**Jim Brown**	1544	111.1	**Jim Brown**	1544	111.1
1964	Jim Brown	1466	87.5	Jim Taylor	1169	98.8

Continued on next page

Table 9 – continued from previous page

Rushing Title Winner				Rusher Rating Winner		
Year	Name	Yds	RR	Name	Yds	RR
1963	**Jim Brown**	1863	106.1	**Jim Brown**	1863	106.1
1962	Jim Taylor	1474	102.6	Abner Haynes	1049	118.4
1961	Jim Brown	1408	85.8	Jim Taylor	1307	112.4
1960	Jim Brown	1257	87.3	Abner Haynes	875	92.2
1959	Jim Brown	1329	97.9	J.D. Smith	1036	99.8
1958	**Jim Brown**	1527	113.5	**Jim Brown**	1527	113.5
1957	**Jim Brown**	942	67.2	**Jim Brown**	942	67.2
1956	Rick Casares	1126	95.5	Frank Gifford	819	99.1
1955	**Alan Ameche**	961	83.6	**Alan Ameche**	961	83.6
1954	**Joe Perry**	1049	90.3	**Joe Perry**	1049	90.3
1953	**Joe Perry**	1018	89.1	**Joe Perry**	1018	89.1
1952	**Dan Towler**	894	96.7	**Dan Towler**	894	96.7
1951	Eddie Price	971	45.2	Dan Towler	854	90.3
1950	**Marion Motley**	810	82.0	**Marion Motley**	810	82.0
Average		1678	89.1		1314	102.8

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