Journal of Quantitative Analysis in Sports

Volume 4, *Issue* 1 | 2008 | *Article* 1

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Recommended Citation:
Fair, Ray C. (2008) "Estimated Age Effects in Baseball," *Journal of Quantitative Analysis in Sports*: Vol. 4: Iss. 1, Article 1.

DOI: 10.2202/1559-0410.1074

Estimated Age Effects in Baseball

Ray C. Fair

Abstract

Age effects in baseball are estimated in this paper using a nonlinear fixed-effects regression. The sample consists of all players who have played 10 or more "full-time" years in the major leagues between 1921 and 2004. Quadratic improvement is assumed up to a peak-performance age, which is estimated, and then quadratic decline after that, where the two quadratics need not be the same. Each player has his own constant term. The results show that aging effects are larger for pitchers than for batters and larger for baseball than for track and field, running, and swimming events and for chess. There is some evidence that decline rates in baseball have decreased slightly in the more recent period, but they are still generally larger than those for the other events. There are 18 batters out of the sample of 441 whose performances in the second half of their careers noticeably exceed what the model predicts they should have been. All but 3 of these players played from 1990 on. The estimates from the fixed-effects regressions can also be used to rank players. This ranking differs from the ranking using lifetime averages because it adjusts for the different ages at which players played. It is in effect an age-adjusted ranking.

KEYWORDS: aging, baseball

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1 Introduction

This paper estimates the effects of aging on the performance of major league baseball players. The performance measures used are on-base percentage (OBP) and on-base percentage plus slugging percentage (OPS) for batters and earned run average (ERA) for pitchers. The paper estimates 1) the rate of improvement up to the peak-performance age, 2) the peak-performance age itself, and 3) the rate of decline after this age. The improving and then declining age profile is assumed to be the same for each player, including the peak-performance age. Each player has his own constant term, however, and so there are n dummy variables in the regression (a fixed-effects regression), where n is the number of players. Both the improving and declining profiles are assumed to follow quadratic processes, where the two processes need not be the same. The restrictions imposed are that the two quadratic processes touch and have zero slopes at the peak-performance age. The model is presented in Section 2; the data are discussed in Section 3; and the estimates are presented in Section 4.

The sample is for the period 1921–2004 (1921 is the first year of the "live" ball). Only players who have played at least 10 "full-time" years in this period are included in the sample, where a full-time year is a year in which a batter played in at least 100 games and a pitcher pitched at least 450 outs. The aim of this paper is to estimate aging effects for injury-free, career baseball players, and the sample was chosen with this in mind. If a batter played fewer than 100 games or a pitcher pitched fewer than 450 outs in a year, it is possible that the player was injured, and so these "part-time" years were excluded. If a player played at least 10 full-time years, he is clearly a career player. The estimated aging effects in this paper are thus conditional on the player being a career player and not affected by injuries. The biological decline rate is being estimated for injury-free players. No attempt is made to estimate the effect of aging on injuries.

There is much work in sabermetrics on developing measures of performance that might be improvements on OBP, OPS, ERA, and the like.[1] The standard measures (like OPS and ERA) are adjusted for issues like 1) the introduction of the designed hitter rule in the American League in 1973, 2) different ball parks that players play in, and 3) different league yearly averages. These kinds of ad-

[1] For example, OPS+ and ERA+ are featured on the website *www.baseball-reference.com*. OPS+ is OPS adjusted for ballparks, the league, and league yearly averages. ERA+ is ERA adjusted for the same things. Another well known measure is Bill James' (2001) Win Shares. Another is LW (linear weights), developed by Thorn and Palmer (1984). Another is EqR (equivalent runs), used, for example, by Silver (2006).

justments, however, are problematic from the point of view of this paper. First, the adjustments tend to be subjective. They are based on particular views about what is and is not important in measuring players' performances, and there are no rigorous ways of testing whether one measure is better than another. Second, and perhaps more important, adjusting for league averages is likely to over adjust a player's performance. If there are fluctuations in league averages over time that have no effect on a player's performance, which seems likely, then it is not appropriate to divide, say, a player's OPS for the year by the league-average OPS for the year to get an "adjusted" OPS for the player. To take an obvious case, say that the league-average OPS increased for the year because a number of players began using steroids, but that player A did not use steroids. If player A's actual OPS were unchanged for the year, then his adjusted OPS would fall because of the higher league average, and this would be an incorrect adjustment. Because of these problems, no adjustments to the standard OBP, OPS, and ERA measures were made for the work in this paper. This work is based on the assumption that the 15-year-or-so period that a player plays is stable for that player. This assumption is obviously only an approximation, since some changes clearly take place within any 15-year period, but it may not be a bad approximation. In future work, however, it may be interesting to experiment with alternative measures.

Once the aging estimates have been obtained, they can be used in a variety of ways. One way, as discussed below, is to compare them to estimates obtained using the "delta approach." This is done in Section 5, where it is argued that the delta approach likely leads to estimated decline rates that are too large. Another way is to search for players who have unusual age-performance profiles. It will be seen that there are 18 batters out of the sample of 441 whose actual OPS values late in their careers are noticeably larger than predicted by the equation. All but 3 of these players played from 1990 on. These results are presented in Section 6.

The estimates can also be compared to those for other events. In previous work—Fair (1994, 2007)—I have estimated decline rates for various track and field, running, and swimming events and for chess. The methodology used in the present paper is quite different from that used in this earlier work, which is based on the use of world records by age, and it is of interest to see how the results compare. It will be seen that the estimated rates of decline in baseball are somewhat larger than those in the other events. These comparisons are discussed in Section 7, where possible reasons for the larger rates in baseball are also discussed.

The stability of the estimates over time is examined in Section 8. There is some evidence that decline rates in baseball are slightly smaller now than they were 40 years ago, although the evidence in general is mixed.

Finally, the estimates provide a way of ranking players that adjusts for the ages at which they played. Take two players, both of whom started at age 23. Say that one played until age 32 and the other played until age 38. Given, as will be seen, that the peak-performance age is about 28, the second player should be expected, other things being equal, to have a worse lifetime performance record because he played a larger fraction of his years below the peak. Ranking players by lifetime OBP, OPS, or ERA does not correct for possible different ages played. One can correct for this, however, by ranking players by the size of the coefficient estimates of the player dummy variables in the regression, i.e., by the players' estimated constant terms. This ranking is discussed in Section 9 and presented in Tables A.1 and A.2 for the sample of 441 batters and 144 pitchers.

Regarding previous work in this area, Bill James is the pioneer in using baseball statistics. In his *1982 Baseball Abstract* he evaluated thousands of ballplayers and concluded that the majority of players peaked at age 27, with most others peaking at age 26 or 28. The results below are consistent with this conclusion. For example, the estimated peak age for batters using the OPS measure is 27.59 years, with an estimated standard error of 0.23 years. One way of estimating aging effects (not just peak ages) in the baseball literature is to use what is sometimes called the "delta approach" (see *www.tangotiger.net/aging.html*). Silver (2006), for example, uses this approach using equivalent runs (EqR) as his measure of performance. The approach is to take, say, all 31 year olds in one's sample who also played when they were 32, compute the average of the measure across these players for age 31 and for age 32, and then compute the percentage change in the two averages. This is the estimated change between ages 31 and 32. Then do the same for ages 32 and 33, where the sample is now somewhat different because the players have had to play at both ages 32 and 33. Continue for each pair of ages. Section 5 argues that this approach is likely to lead to biased estimates—to estimated rates of decline at the older ages that are too large. The delta approach does not appear to be a reliable way of estimating aging effects.

Schultz, Musa, Staszewski, and Siegler (1994) use a sample of 235 batters and 153 pitchers, players who were active in 1965. They compute averages by age. Using these averages for a variety of performance measures, they find the peak-performance age to be about 27 for batters and 29 for pitchers. As will be seen, the 27 age for batters is close to the estimates in this paper, but the 29 age for pitchers is noticeably larger. As they note (pp. 280–281), their averages cannot be used to estimate rates of decline because of selection bias (better players on average retire later). Schell (2005, Chapter 4) also computes averages by age and also notes (p. 46) the selection bias problem. He presents plots of these averages for various performance measures, but does not use them because of the bias problem. He adjusts his performance measures using data on the ages at which players reached various milestones, like 1000 at bats, 2000 at bats, etc. He does not attempt to estimate rates of decline.

The two studies closest to the present one are Berry, Reese, and Larkey (1999) and Albert (2002). Albert (2002), using LW (linear weights) as the measure of performance, estimates a quadratic aging function for each player separately and then combines the regression estimates using a Bayesian exchangeable model. The estimates are made separately by decade. Albert assumes that the quadratic is symmetric around the peak age. Barry, Rees, and Larkey (1999) postulate an asymmetric, nonparametric aging function that is the same for all players. They are also concerned with player differences across decades, and they use hierarchical models to model the distribution of players for each decade. More will be said about both of these studies in the next section.

2 The Model

Let y_{it} denote the measure of performance for player i in year t (either OBP, OPS, or ERA), and let x_{it} denote the age of player i in year t. The model for player i is:

$$y_{it} = \begin{cases} \alpha_{1i} + \beta_1 x_{it} + \gamma_1 x_{it}^2 + \epsilon_{it}, & x_{it} \leq \delta \\ \alpha_{2i} + \beta_2 x_{it} + \gamma_2 x_{it}^2 + \epsilon_{it}, & x_{it} \geq \delta \end{cases} \tag{1}$$

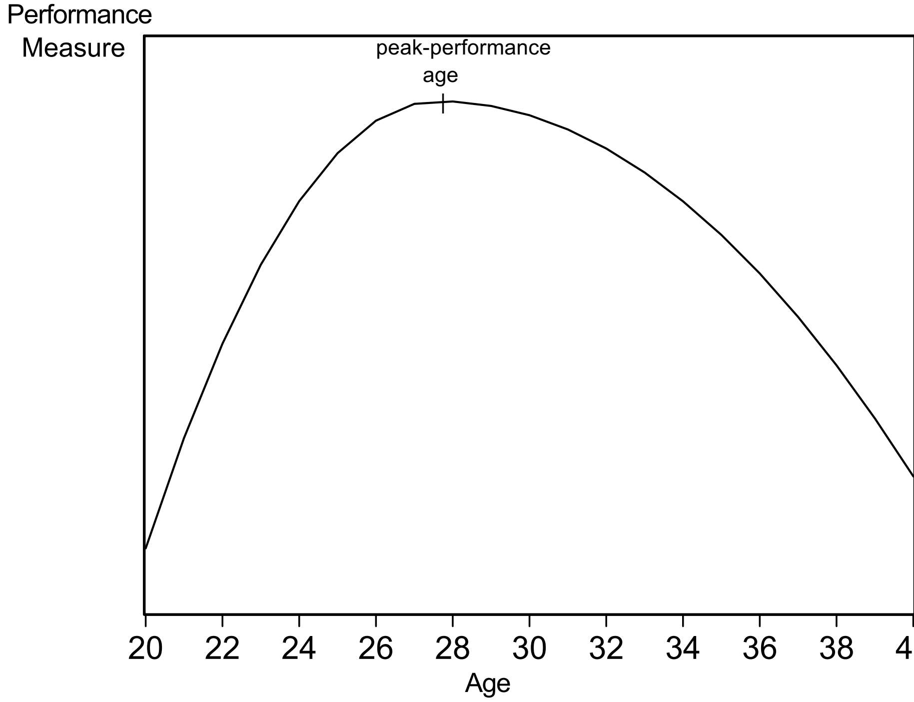
δ is the peak-performance age, and ϵ_{it} is the error term. As noted in the Introduction, the two quadratic equations are constrained to have zero derivatives and touch at $x_{it} = \delta$. This imposes the following three constraints on the coefficients:

$$\begin{aligned} \beta_1 &= -2\gamma_1\delta \\ \beta_2 &= -2\gamma_2\delta \\ \alpha_{2i} &= \alpha_{1i} + (\gamma_2 - \gamma_1)\delta^2 \end{aligned} \tag{2}$$

Figure 1 presents a plot of what is being assumed.[2] There is quadratic improvement up to δ and quadratic decline after δ, where the two quadratics can differ. The unconstrained coefficients to estimate are γ_1, γ_2, δ, and α_{1i}.

[2]For batters large values of OBP and OPS are good, and for pitchers small values of ERA are good. Figure 1 and the discussion in this section assumes that large values are good. It is straightforward to adjust the discussion for ERA.

Figure 1
Postulated Relationship Between Performance and Age



Each player is assumed to have his own α_{1i} (and thus his own α_{2i} from equation (2)). Let p_{jit} be a dummy variable for player j that is equal to 1 if $j = i$ and 0 otherwise, and let d_{it} be a dummy variable that is equal to 1 if $x_{it} \leq \delta$ and 0 otherwise. Then the equation to be estimated is:

$$\begin{array}{c} y_{it} = \sum_{j=1}^{J} \alpha_{1j} p_{jit} + \gamma_1[(\delta^2 - 2\delta x_{it} + x_{it}^2)d_{it}] \\ +\gamma_2[-\delta^2 d_{it} + (x_{it}^2 - 2\delta x_{it})(1 - d_{it})] + \epsilon_{it} \quad , \\ d_{it} = 1 \quad \text{if} \quad x_{it} \leq \delta \quad \text{and} \;\; 0 \;\; \text{otherwise} \end{array} \tag{3}$$

where J is the total number of players. In this equation i runs from 1 to J. For each player, t runs over the years that he played. ϵ_{it} is assumed to be *iid* and to be uncorrelated with the age variables.

The coefficients to estimate in equation (3) are the J values of the alphas, γ_1, γ_2, and δ. If δ is known, the two terms in brackets are known, and so the equation is linear in coefficients. The equation can then be estimated by the standard fixed-effects procedure of time-demeaning the data. Overall estimation can thus be done by trying many values of δ to find the value that minimizes the sum of squared residuals. This does not, however, produce correct standard errors because the uncertainty of the estimate of δ is not taken into account. Equation (3) must be estimated by nonlinear least squares to get correct standard errors. This is a large nonlinear maximization problem because of the large number of dummy variable coefficients estimated.

The key assumption of the model is that all players have the same $\beta's$ and $\gamma's$, i.e., the same improving and declining rates. Given this, the specification is fairly flexible in allowing the improving rate to differ from the declining rate and in allowing the peak-performance age to be estimated. Each player has, of course, his own constant term, which in Figure 1 determines the vertical position of the curve.

In the table of results below, estimates of γ_1, γ_2, and δ are presented. In addition, some implied values by age are presented. Consider the following:

$$R_k = \hat{y}_{it}|(x_{it} = k) - \hat{y}_{is}|(x_{is} = \hat{\delta}) \tag{4}$$

The first term on the right hand side is the predicted value for player i at age k, and the second term is the predicted value for player i at the estimated peak-performance age $\hat{\delta}$. R_k is the same for all players because a player's constant term appears additively in both predicted values and so cancels out. R_k thus does not need an i subscript. It is the amount by which a player at age k is below his estimated peak. Values of R_k for different values of k are presented in the table below.

DOI: 10.2202/1559-0410.1074

The derivative of y_{it} with respect to x_{it} is

$$\partial y_{it}/\partial x_{it} = 2\gamma_1(x_{it} - \delta)d_{it} + 2\gamma_2(x_{it} - \delta)(1 - d_{it}) \tag{5}$$

This derivative is not a function of a player's constant term, and so it is the same for all players of the same age. Let

$$D_k = 100\frac{(\partial y_{it}/\partial x_{it})|(x_{it} = k)}{\bar{y}} \tag{6}$$

where $\bar{y}$ is the mean of y_{it} over all the observations. D_k is roughly the percentage change in y for a player at age k. It is only roughly the percentage change because $\bar{y}$ is used in the denominator rather than a specific player's predicted value at the relevant age. Values of D_k for different values of k are also presented in the table below.

This model relative to the models of Berry, Reese, and Larkey (1999) and Albert (2002), discussed at the end of the Introduction, is parsimonious. Only three coefficient estimates are estimated aside from the constant term for each player. It will be seen that this leads to very precise coefficient estimates—a precisely estimated age profile. Although Albert (2002) restricts the quadratic to be symmetric around the peak age, which according to the results below is not the case, his method has the advantage of not having to assume that the aging profile is the same for all players. The disadvantage is that even with the Bayesian model that he uses, many parameters are in effect being estimated, and so the precision may be low. Berry, Reese, and Larkey (1999) assume, as is done in this paper, that the age profile is the same for all players, but they also in effect estimate many more parameters because, among other things, of their assumption that players differ across decades.

A potential cost of the present approach is that the assumption of a constant age profile across players and over time may not be accurate, which means that the model may be misspecified. One way in which the model may be misspecified is the following. Say there is a variable like body mass that is different for each player but that does not change for a given player across his career. If, say, body mass has no effect on a player's performance until age 37, at which point a larger body mass has a negative effect on performance, then ϵ_{it}, which includes the effects of omitted variables like body mass, will be correlated with age from age 37 on, thus violating the assumption about the error term. Another possibility is that there may be "ageless wonders," who simply decline at slower rates as they age relative to other players. These players will have positive values of ϵ_{it} at older ages, and so

ϵ_{it} will be correlated with age at older ages, again violating the assumption about the error term. One check of the quantitative importance of these types of bias is to examine the sensitivity of the results to the exclusion of older players. As discussed in the next section, regressions were also run excluding players older than 37. It will be seen that the results are not sensitive to this exclusion, and so these potential biases do not appear large. Also, the results in Section 8 show that the estimates are fairly stable using each half of the sample period.

One selection issue that is not a problem in the present model is the following. Say that an older player is considering retiring, but in the current year he is doing better than might be expected given his age—his error term is positive. He may then choose to play another year, and so the next year will be in the sample. This does not violate the assumption that age and the error term are uncorrelated as long as the error term is not serially correlated. In this example, last year's error affects the decision to play this year, but this has no effect on this year's error term, again assuming no serial correlation.

One final issue concerns experience. If the improvement of a player up to the peak-performance age is interpreted as the player gaining experience (as opposed to, say, just getting physically better), this experience according to the assumptions of the model comes with age, not with the number of years played in the major leagues. A player coming into the major leagues at, say, age 26 is assumed to be on the same age profile as an age-26 player who has been in the major leagues for 4 years. In other words, minor league experience must be assumed to be the same as major league experience.

3 The Data

Yearly data on every player who played major league baseball from 1871 on are available from *http://baseball1.com*. As noted in the Introduction, the period used is 1921–2004 and only players who have played at least 10 full-time years in this period are included in the sample, where a full-time year is a year in which a batter played in at least 100 games and a pitcher pitched at least 450 outs. Almost all relief pitchers are excluded from the sample because almost no relief pitcher pitches as many as 450 outs in a year. The sample for batters included 5,596 observations and 441 players, and the sample for pitchers included 1,809 observations and 144 players. These players are listed in Tables A.1 and A.2.

Players who are included in the sample may have played non full-time years, but these years for the player are not in the sample. Players who played beyond

2004 are included in the sample if they have 10 full-time years from 2004 back. Players who began playing prior to 1921 are included if they have 10 full-time years from 1921 forward, but their observations prior to 1921 are not included even if the observations are for full-time years because no observations before 1921 are used.

On-base percentage (OBP) is equal to (hits + bases on balls + hit by pitch) divided by (at bats + bases on balls + hit by pitch + sacrifice flies). Slugging percentage is equal to (hits + doubles + 2 times triples + 3 times home runs) divided by at bats. OPS is equal to OBP + slugging percentage. Earned run average (ERA) is equal to the number of earned runs allowed divided by (the number of outs made divided by 27). These are all standard definitions. The age of the player was computed as the year in question minus the player's birth year.

Some alternative regressions were run to examine the sensitivity of the estimates, and these are reported below. For batters the exclusion restrictions were changed to 80 games rather than 100 and 8 years rather than 10. This gave 10,605 observations for 932 players. For pitchers the exclusion was changed to 8 years rather than 10. This gave 2,775 observations for 260 players. Another change was to drop all observations in which a player was older than 37 years (but keeping a player in even if this resulted in fewer than 10 full-time years for the player). This resulted in 5,308 observations for the 441 batters and 1,615 observations for the 144 pitchers.

4 The Results

All the estimates are presented in Table 1. The first set of three uses OPS, the second set uses OBP, and the third set uses ERA. The first estimate for each set is the basic estimate; the second estimate is for the larger number of observations; and the third estimate excludes observations in which the player is over 37. Estimated standard errors for the coefficient estimates are presented for the basic estimate for each set. As noted above, the model is nonlinear in coefficients, and for present purposes the DFP algorithm was used to obtain the estimates.[3] The implied values

[3]This is a large nonlinear maximization problem. There are 444 coefficients to estimate: γ_1, γ_2, δ, and the 441 dummy variable coefficients. These calculations were done using the Fair-Parke program (2003). The standard errors of the coefficient estimates were computed as follows. Let $f(y_j, x_j, \alpha) = u_j$ be the equation being estimated, where y_j is the dependent variable, x_j is the vector of explanatory variables, α is the vector of coefficients to estimate, and u_j is the error term. j indexes the number of observations; assume that it runs from 1 to J. Let K be the dimension of

Table 1
Coefficient Estimates and Implied Aging Values

	Estimate of γ_1	γ_2	δ	SE	#obs (#plys)	R_k, (D_k) by age 22	25	28	31	34	37	40
OPS												
1	-0.001618	-0.000508	27.59	.0757	5596	-0.051	-0.011	0.000	-0.006	-0.021	-0.045	-0.078
	(.000205)	(.000021)	(0.23)		(441)	(2.28)	(1.06)	(-0.05)	(-0.44)	(-0.82)	(-1.21)	(-1.59)
2	-0.001617	-0.000550	27.60	.0758	10605	-0.051	-0.011	0.000	-0.006	-0.023	-0.049	-0.085
					(932)	(2.36)	(1.10)	(-0.06)	(-0.49)	(-0.92)	(-1.35)	(-1.78)
3	-0.001483	-0.000609	27.90	.0749	5308	-0.052	-0.012	0.000	-0.006	-0.023	-0.050	-0.089
					(441)	(2.20)	(1.08)	(-0.02)	(-0.47)	(-0.93)	(-1.39)	(-1.85)
OBP												
1	-0.0005289	-0.0001495	28.30	.0276	5596	-0.021	-0.006	0.000	-0.001	-0.005	-0.011	-0.020
	(.0000621)	(.000074)	(0.26)		(441)	(1.88)	(0.99)	(0.09)	(-0.23)	(-0.48)	(-0.73)	(-0.99)
2	-0.0005252	-0.0001634	28.30	.0281	10605	-0.021	-0.006	0.000	-0.001	-0.005	-0.012	-0.022
					(932)	(1.91)	(1.00)	(0.09)	(-0.26)	(-0.54)	(-0.82)	(-1.11)
3	-0.0005032	-0.0001742	28.50	.0271	5308	-0.021	-0.006	0.000	-0.001	-0.005	-0.013	-0.023
					(441)	(1.84)	(0.99)	(0.14)	(-0.25)	(-0.54)	(-0.83)	(-1.13)
ERA												
1	0.006520	0.002872	26.54	.6845	1809	0.134	0.015	0.006	0.057	0.160	0.314	0.520
	(.005388)	(.000658)	(1.40)		(144)	(-1.69)	(-0.57)	(0.24)	(0.73)	(1.22)	(1.72)	(2.21)
2	0.021474	0.002265	24.00	.6910	2775	0.086	0.002	0.036	0.111	0.226	0.383	0.580
					(260)	(-2.40)	(0.13)	(0.51)	(0.89)	(1.27)	(1.64)	(2.02)
3	0.011821	0.001926	25.20	.6848	1615	0.121	0.000	0.015	0.065	0.149	0.268	0.422
					(144)	(-2.17)	(-0.14)	(0.31)	(0.64)	(0.97)	(1.31)	(1.64)

Notes:
- Standard errors are in parentheses for the coefficient estimates.
- lines 1 and 3: 10 full-time years between 1921 and 2004; full-time year: 100 games for batters, 150 innings for pitchers.
- lines 3: player observation excluded if player aged 38 or over.
- lines 2: 8 full-time years between 1921 and 2004; full-time year: 80 games for batters, 150 innings for pitchers.
- R_k defined in equation (4); D_k defined in equation (6).
- Dummy variable included for each player. Dummy variable coefficient estimates presented in Table A.1 for OPS line 1 and OBP line 1 and in Table A.2 for ERA line 1 under the heading CNST.
- The mean of all the observations ($\bar{y}$ in the text) is .793 OPS, line 1, .766 OPS, line 2, .795 OPS, line 3, .354 OBP, line 1, .346 OPS, line 2, .355 OPS, line 3, 3.50 ERA, line 1, 3.58 ERA, line 2, 3.48 ERA, line 3.

for R_k and D_k are presented for k equal to 22, 25, 28, 31, 34, 37, and 40. Remember that R_k is the amount by which a player at age k is below his estimated peak and that D_k is roughly the percentage change in the performance measure at age k.

A general result in Table 1 is that the estimates are not sensitive to the increase in the number of players (by using 8 years as the cutoff instead of 10 years and by using for batters 80 games played in a year instead of 100) and to the exclusion of observations in which the player was older than 37. Compare, for example, the values of R_k and D_k for $k = 40$ in lines 1, 2, and 3 for each of the three measures. The following discussion will thus concentrate on the basic estimate—line 1—for each set.

α (K coefficients to estimate). Let G' be the $K \times J$ matrix whose jth column is $\partial f(y_j, x_j, \alpha)/\partial\alpha$. The estimated covariance matrix of $\hat{\alpha}$ is $\hat{\sigma}^2(\hat{G}'\hat{G})^{-1}$, where $\hat{\sigma}^2$ is the estimate of the variance of u_j and $\hat{G}$ is G evaluated at $\alpha = \hat{\alpha}$. For regression 1 for batters J is 5596 and K is 444. For regression 1 for pitchers J is 1809 and K is 147.

DOI: 10.2202/1559-0410.1074

Another general result in Table 1 is that the estimated rate of improvement before the peak-performance age is larger than the estimated rate of decline after the age. In other words, the learning curve at the beginning of a player's career is steeper than the declining curve after the peak-performance age.

Turning now to the basic estimates, for OPS δ is 27.6 years and by age 37 the percentage rate of decline is 1.21 percent. For OBP the respective numbers are 28.3 years and 0.73 percent. The peak-performance ages are thus quite similar for the two measures, but OPS declines somewhat more rapidly than OBP. To get a sense of magnitudes, if a player's peak OPS is 0.800 (the mean of OPS in the sample is 0.793), then the -0.045 value for R_{37} means that his predicted OPS at age 37 is 0.755, a decrease of 5.6 percent. Similarly, if a player's peak OBP is 0.350 (the mean of OBP is the sample is 0.354), then the -0.011 value for R_{37} means that his predicted OBP at age 37 is 0.339, a decrease of 3.1 percent.

For ERA δ is 26.5 and by age 37 the percentage rate of decline is 1.72 percent. If a pitcher's peak ERA is 3.50 (the mean of ERA in the sample is 3.50), then the 0.314 value for R_{37} means that his predicted ERA at age 37 is 3.814, an increase of 9.0 percent. The estimated decline for pitchers is thus somewhat larger than for batters, and the peak-performance age is slightly lower.

The precision of the estimates is fairly good, although better for batters than for pitchers. The estimated standard error for the estimated peak-performance age is 0.23 years for OPS and 0.26 years for OBP. For ERA it is 1.40 years. The sample period for pitchers is about a third the size of the period for batters, which at least partly accounts for the less precision for pitchers.

5 Comparison to the Delta Approach

As discussed in the Introduction, the delta approach has been used to measure aging effects. For example, Silver (2006, Table 7-3.4, p. 263) has used it for post World War II batters and the EqR measure. To examine this approach further, Table 2 presents estimated decline rates using the delta approach for the sample of 441 batters used in this paper and the OBP measure. For example, there were 344 of the 441 batters who played full time when they were both 32 and 33. The average OBP for this group was .3609 for age 32 and .3560 for age 33, which is a decline of 1.36 percent. There were then 315 of the 441 batters who played full time when they were both 33 and 34. The average OBP for this group was .3577 for age 33 and .3537 for age 34, which is a decline of 1.12 percent.

Table 2
Estimated Decline Rates Using the Delta Approach

Ages	# obs.	First Age OBP ave.	Second Age OBP ave.	% change
21–22	55	.3404	.3468	1.88
22–23	133	.3412	.3493	2.37
23–24	226	.3491	.3533	1.20
24–25	273	.3483	.3544	1.75
25–26	333	.3516	.3570	1.54
26–27	362	.3559	.3569	0.28
27–28	380	.3576	.3582	0.17
28–29	381	.3588	.3586	−0.00
29–30	368	.3590	.3577	−0.36
30–31	375	.3585	.3610	0.70
31–32	359	.3609	.3599	−0.28
32–33	344	.3609	.3560	−1.36
33–34	315	.3577	.3537	−1.12
34–35	263	.3578	.3511	−1.87
35–36	210	.3544	.3508	−1.02
36–37	146	.3545	.3525	−0.56
37–38	96	.3543	.3480	−1.78
38–39	64	.3599	.3530	−1.92
39–40	39	.3685	.3597	−2.39
40–41	22	.3585	.3439	−4.07

Comparing Tables 1 and 2, it is obvious that the decline rates are larger in Table 2. In Table 1 for OBP, line 1, the decline rate is 0.48 percent for age 34, 0.73 percent for age 37, and 0.99 percent for age 40. In Table 2 the decline rate is 1.87 percent for age 34, 1.78 percent for age 37, and 4.07 percent for age 40. What can account for these large differences? A likely answer is that the delta approach overestimates decline rates at the older ages—that the delta-approach decline-rate estimates are biased. The reason is the following. First, note in Table 2 that the sample size drops fairly rapidly after age 32. Now consider a player who is thinking about retiring and who has had a better than average year for him. "Better-than-average" means that his error term in equation (1) is positive. This is likely to increase the chances that he chooses to play the next year. If players' error terms are uncorrelated across years, then a positive error in one year does not increase the chances of a positive error the next year. Our player is expected to have an average year (for him) the next year—an expected zero error term. If it turns out that he in fact has an average (or below average) year, this may lead him to retire at the end of the season. So error terms for players in their penultimate year are likely to be on average higher than the error terms in their last year. Players don't retire as often when error terms are large. The delta approach will thus be biased at the older ages because the paired sample that is used will have on average larger errors for the younger of the two ages.

This bias can in fact been seen in the sample used in this paper. Of the 441 batters in the sample, 401 had retired. The average of the error terms for the last observation for each of these 401 players, using the error terms for the OBP regression in Table 1, line 1, is -0.00954, which is smaller than the average of the error terms from the second-to-last observation of -0.00448. (The last observation in the sample for a player is usually the year in which he retired.) So there is evidence that a player's error term is lower in the year in which he retires than in the year before he retires, thus leading the delta approach to be biased. Comparing the estimates in Tables 1 and 2 suggests that the bias is quite large.

6 Unusual Age-Performance Profiles

Since there is a dummy variable for each player, the sum of a player's residuals across the years that he played is zero. Under the assumption that the errors, ϵ_{it}, are *iid*, they should lie randomly around the age-performance curve in Figure 1 for each player. It is interesting to see if there are players whose patterns are noticeably different. For example, if a player got better with age, contrary to the assumptions of the model, one would see in Figure 1 large negative residuals at the young ages and large positive residuals at the old ages.

Using OPS regression 1 in Table 1, the following procedure was followed to choose players who have a pattern of large positive residuals in the second half of their careers. First, all residuals greater than one standard error (.0757) were recorded. Then a player was chosen if he had four or more of these residuals from age 28, the estimated peak-performance age, on. There were a total of 17 such players. In addition, for reasons discussed below, Rafael Palmeiro was chosen, giving a total of 18 players. The age-performance results for these players are presented in Table 3. The residuals in bold are greater than one standard error. The players are listed in alphabetic order except for Palmeiro, who is listed last.

The most remarkable performance by far in Table 3 is that of Barry Bonds. Three of his last four residuals (ages 37–40) are the largest in the sample period, and the last one is 5.5 times the estimated standard error of the equation. Not counting Bonds, Sammy Sosa has the largest residual (age 33, 2001) and Luis Gonzalez has the second largest (age 34, 2001). Mark McGwire has three residuals that are larger than two standard errors (age 33, 1996; age 35, 1998; age 36, 1999). Larry

Table 3
Age-Performance Results for Eighteen Players: OPS

Year	Age	Pred.	Act.	Resid.	Year	Age	Pred.	Act.	Resid.
Albert Belle					**Bob Boone**				
1991	25	0.946	0.863	-0.083	1973	26	0.700	0.675	-0.025
1992	26	0.952	0.797	-0.155	1974	27	0.704	0.617	-0.087
1993	27	0.956	0.922	-0.034	1976	29	0.703	0.713	0.010
1994	28	0.956	1.152	**0.196**	1977	30	0.701	0.780	**0.079**
1995	29	0.955	1.091	**0.136**	1978	31	0.698	0.772	0.074
1996	30	0.954	1.033	**0.079**	1979	32	0.694	0.789	**0.094**
1997	31	0.951	0.823	-0.128	1980	33	0.689	0.637	-0.052
1998	32	0.947	1.055	**0.108**	1982	35	0.676	0.647	-0.029
1999	33	0.942	0.941	0.000	1983	36	0.668	0.641	-0.027
2000	34	0.936	0.817	-0.119	1984	37	0.659	0.504	-0.155
					1985	38	0.649	0.623	-0.026
					1986	39	0.638	0.593	-0.046
					1987	40	0.626	0.615	-0.011
					1988	41	0.613	0.739	**0.126**
					1989	42	0.599	0.675	**0.076**
Barry Bonds					**Ken Caminiti**				
1986	22	1.035	0.746	-0.289	1989	26	0.803	0.685	-0.118
1987	23	1.051	0.821	-0.231	1990	27	0.807	0.611	-0.196
1988	24	1.065	0.859	-0.206	1991	28	0.807	0.695	-0.113
1989	25	1.075	0.777	-0.298	1992	29	0.807	0.790	-0.016
1990	26	1.081	0.970	-0.111	1993	30	0.805	0.711	-0.093
1991	27	1.085	0.924	-0.161	1994	31	0.802	0.847	0.046
1992	28	1.085	1.080	-0.006	1995	32	0.798	0.894	**0.096**
1993	29	1.084	1.136	0.051	1996	33	0.793	1.028	**0.236**
1994	30	1.083	1.073	-0.009	1997	34	0.787	0.897	**0.110**
1995	31	1.080	1.009	-0.071	1998	35	0.780	0.862	**0.082**
1996	32	1.076	1.076	0.000	2001	38	0.753	0.719	-0.033
1997	33	1.071	1.031	-0.040					
1998	34	1.065	1.047	-0.018					
1999	35	1.058	1.006	-0.051					
2000	36	1.050	1.127	**0.078**					
2001	37	1.041	1.379	**0.338**					
2002	38	1.031	1.381	**0.350**					
2003	39	1.019	1.278	**0.258**					
2004	40	1.007	1.422	**0.414**					
Chili Davis					**Dwight Evans**				
1982	22	0.786	0.719	-0.067	1973	22	0.806	0.703	-0.103
1983	23	0.802	0.657	-0.145	1974	23	0.823	0.756	-0.067
1984	24	0.816	0.875	0.059	1975	24	0.836	0.809	-0.027
1985	25	0.825	0.761	-0.065	1976	25	0.846	0.755	-0.091
1986	26	0.832	0.791	-0.041	1978	27	0.856	0.784	-0.072
1987	27	0.836	0.786	-0.049	1979	28	0.857	0.820	-0.036
1988	28	0.836	0.757	-0.079	1980	29	0.856	0.842	-0.014
1989	29	0.835	0.775	-0.060	1981	30	0.854	0.937	**0.083**
1990	30	0.833	0.755	-0.078	1982	31	0.851	0.936	**0.085**
1991	31	0.830	0.892	0.062	1983	32	0.847	0.774	-0.072
1992	32	0.827	0.825	-0.002	1984	33	0.842	0.920	**0.078**
1993	33	0.822	0.767	-0.055	1985	34	0.836	0.832	-0.004
1994	34	0.816	0.971	**0.156**	1986	35	0.829	0.853	0.024
1995	35	0.809	0.943	**0.135**	1987	36	0.821	0.986	**0.166**
1996	36	0.801	0.884	**0.083**	1988	37	0.812	0.861	0.050
1997	37	0.791	0.896	**0.104**	1989	38	0.802	0.861	0.059
1999	39	0.770	0.812	0.041	1990	39	0.791	0.740	-0.051
					1991	40	0.779	0.771	-0.007

Table 3 (continued)

Year	Age	Pred.	Act.	Resid.	Year	Age	Pred.	Act.	Resid.
Steve Finley					**Julio Franco**				
1990	25	0.801	0.632	-0.169	1983	25	0.824	0.693	-0.131
1991	26	0.808	0.737	-0.071	1984	26	0.831	0.679	-0.152
1992	27	0.811	0.762	-0.049	1985	27	0.834	0.723	-0.111
1993	28	0.812	0.689	-0.123	1986	28	0.835	0.760	-0.074
1995	30	0.809	0.786	-0.023	1987	29	0.834	0.818	-0.016
1996	31	0.806	0.885	**0.079**	1988	30	0.832	0.771	-0.061
1997	32	0.802	0.788	-0.014	1989	31	0.829	0.848	0.019
1998	33	0.797	0.702	-0.096	1990	32	0.825	0.785	-0.040
1999	34	0.791	0.861	0.070	1991	33	0.820	0.882	0.062
2000	35	0.784	0.904	**0.120**	1993	35	0.807	0.798	-0.009
2001	36	0.776	0.767	-0.009	1994	36	0.799	0.916	**0.117**
2002	37	0.767	0.869	**0.102**	1996	38	0.780	0.877	**0.097**
2003	38	0.757	0.863	**0.105**	1997	39	0.769	0.730	-0.039
2004	39	0.746	0.823	**0.077**	2002	44	0.698	0.739	0.040
					2003	45	0.681	0.824	**0.143**
					2004	46	0.663	0.818	**0.155**
Gary Gaetti					**Andres Galarraga**				
1982	24	0.744	0.723	-0.021	1986	25	0.866	0.743	-0.123
1983	25	0.754	0.724	-0.030	1987	26	0.873	0.821	-0.052
1984	26	0.761	0.665	-0.095	1988	27	0.876	0.893	0.017
1985	27	0.764	0.710	-0.054	1989	28	0.877	0.761	-0.116
1986	28	0.765	0.865	**0.101**	1990	29	0.876	0.715	-0.161
1987	29	0.764	0.788	0.024	1991	30	0.874	0.604	-0.270
1988	30	0.762	0.905	**0.143**	1993	32	0.867	1.005	**0.138**
1989	31	0.759	0.690	-0.069	1994	33	0.862	0.949	**0.087**
1990	32	0.755	0.650	-0.105	1995	34	0.856	0.842	-0.014
1991	33	0.750	0.672	-0.078	1996	35	0.849	0.958	**0.109**
1992	34	0.744	0.610	-0.134	1997	36	0.841	0.974	**0.133**
1993	35	0.737	0.738	0.001	1998	37	0.832	0.991	**0.159**
1995	37	0.720	0.846	**0.126**	2000	39	0.811	0.895	**0.084**
1996	38	0.710	0.799	**0.090**	2001	40	0.799	0.784	-0.014
1997	39	0.699	0.710	0.011	2002	41	0.785	0.738	-0.047
1998	40	0.687	0.852	**0.165**	2003	42	0.771	0.841	0.069
1999	41	0.673	0.599	-0.074					
Charlie Gehringer					**Luis Gonzalez**				
1926	23	0.862	0.721	-0.141	1991	24	0.842	0.753	-0.088
1927	24	0.875	0.824	-0.052	1992	25	0.852	0.674	-0.177
1928	25	0.885	0.846	-0.039	1993	26	0.858	0.818	-0.040
1929	26	0.892	0.936	0.045	1994	27	0.862	0.782	-0.080
1930	27	0.895	0.938	0.043	1995	28	0.862	0.812	-0.051
1931	28	0.896	0.790	-0.106	1996	29	0.861	0.797	-0.065
1932	29	0.895	0.867	-0.028	1997	30	0.859	0.722	-0.138
1933	30	0.893	0.862	-0.031	1998	31	0.857	0.816	-0.041
1934	31	0.890	0.967	**0.077**	1999	32	0.853	0.952	**0.099**
1935	32	0.886	0.911	0.025	2000	33	0.848	0.935	**0.088**
1936	33	0.881	0.987	**0.106**	2001	34	0.842	1.117	**0.275**
1937	34	0.875	0.978	**0.102**	2002	35	0.835	0.896	0.061
1938	35	0.868	0.911	0.043	2003	36	0.827	0.934	**0.107**
1939	36	0.860	0.967	**0.107**	2004	37	0.818	0.866	0.048
1940	37	0.851	0.875	0.024					
1941	38	0.841	0.666	-0.175					

Table 3 (continued)

Year	Age	Pred.	Act.	Resid.	Year	Age	Pred.	Act.	Resid.
Mark McGwire					**Paul Molitor**				
1987	24	0.981	0.987	0.007	1978	22	0.805	0.673	-0.132
1988	25	0.991	0.830	-0.161	1979	23	0.822	0.842	0.020
1989	26	0.997	0.806	-0.191	1980	24	0.835	0.809	-0.025
1990	27	1.001	0.859	-0.142	1982	26	0.851	0.816	-0.035
1991	28	1.002	0.714	-0.288	1983	27	0.855	0.743	-0.112
1992	29	1.001	0.970	-0.031	1985	29	0.855	0.764	-0.091
1995	32	0.992	1.125	**0.134**	1986	30	0.853	0.765	-0.087
1996	33	0.987	1.198	**0.211**	1987	31	0.850	1.003	**0.153**
1997	34	0.981	1.039	0.058	1988	32	0.846	0.836	-0.010
1998	35	0.974	1.222	**0.249**	1989	33	0.841	0.818	-0.023
1999	36	0.966	1.120	**0.155**	1990	34	0.835	0.807	-0.028
					1991	35	0.828	0.888	0.060
					1992	36	0.820	0.851	0.031
					1993	37	0.811	0.911	**0.101**
					1994	38	0.801	0.927	**0.127**
					1995	39	0.790	0.772	-0.017
					1996	40	0.778	0.858	**0.081**
					1997	41	0.764	0.786	0.022
					1998	42	0.750	0.718	-0.033
Sammy Sosa					**B.J. Surhoff**				
1990	22	0.854	0.687	-0.167	1987	23	0.732	0.773	0.041
1991	23	0.870	0.576	-0.294	1988	24	0.745	0.611	-0.134
1993	25	0.893	0.794	-0.099	1989	25	0.755	0.626	-0.129
1994	26	0.900	0.884	-0.016	1990	26	0.762	0.706	-0.056
1995	27	0.904	0.840	-0.063	1991	27	0.766	0.691	-0.075
1996	28	0.904	0.888	-0.016	1992	28	0.766	0.635	-0.131
1997	29	0.903	0.779	-0.124	1993	29	0.765	0.709	-0.056
1998	30	0.901	1.024	**0.122**	1995	31	0.760	0.870	**0.109**
1999	31	0.898	1.002	**0.103**	1996	32	0.756	0.834	**0.078**
2000	32	0.894	1.040	**0.145**	1997	33	0.751	0.803	0.052
2001	33	0.889	1.174	**0.285**	1998	34	0.745	0.789	0.044
2002	34	0.883	0.993	**0.110**	1999	35	0.738	0.839	**0.101**
2003	35	0.876	0.911	0.035	2000	36	0.730	0.787	0.057
2004	36	0.868	0.849	-0.020	2001	37	0.721	0.726	0.004
					2004	40	0.688	0.785	**0.097**
Larry Walker					**Rafael Palmeiro**				
1990	24	0.967	0.761	-0.207	1988	24	0.893	0.785	-0.108
1991	25	0.977	0.807	-0.170	1989	25	0.903	0.728	-0.175
1992	26	0.984	0.859	-0.125	1990	26	0.910	0.829	-0.081
1993	27	0.988	0.841	-0.147	1991	27	0.914	0.922	0.008
1994	28	0.988	0.981	-0.007	1992	28	0.914	0.786	-0.128
1995	29	0.987	0.988	0.001	1993	29	0.913	0.926	0.013
1997	31	0.982	1.172	**0.189**	1994	30	0.911	0.942	0.031
1998	32	0.978	1.075	**0.096**	1995	31	0.908	0.963	0.055
1999	33	0.974	1.168	**0.195**	1996	32	0.904	0.927	0.023
2001	35	0.961	1.111	**0.151**	1997	33	0.899	0.815	-0.085
2002	36	0.952	1.023	0.071	1998	34	0.893	0.945	0.051
2003	37	0.943	0.898	-0.046	1999	35	0.886	1.050	**0.164**
					2000	36	0.878	0.954	**0.076**
					2001	37	0.869	0.944	0.075
					2002	38	0.859	0.962	**0.103**
					2003	39	0.848	0.867	0.019
					2004	40	0.836	0.796	-0.040

- Act. = actual OPS, Pred. = predicted OPS, Resid. = Act. - Pred.
- Resid. sums to zero across time for each player.
- Values of Resid. greater than one standard error are in **bold.**
- Equation is OPS line 1 in Table 1. Standard error is .0757.
- Resid. in 2001 for Palmeiro is .0750.

DOI: 10.2202/1559-0410.1074

Walker has two residuals that are larger than two standard errors (age 31, 1997; age 33, 1999) and one that is nearly two standard errors (age 35, 2001). Aside from the players just mentioned, 8 other players have one residual greater than two standard errors: Albert Belle (age 28, 1994), Ken Caminiti (age 33, 1996), Chili Davis (age 34, 1994), Dwight Evans (age 36, 1987), Julio Franco (age 46, 2004), Gary Gaetti (age 40, 1998), Andres Galarraga (age 37, 1998), and Paul Molitor (age 31, 1987).

There are only 3 players in Table 3 who did not play more than half their careers in the 1990s and beyond: Bob Boone (1973–1989), Dwight Evans (1973–1991), and Charlie Gehringer (1926–1941). Remember that the period searched was 1921–2004, so this concentration is unusual. An obvious question is whether performance-enhancing drugs had anything to do with this concentration. In 2005 Palmeiro tested positively for steroids, and so it is of interest to see what his age-performance results look like. He is listed last in Table 3. Palmeiro's pattern looks similiar to that of many of the others in the table. He has three residuals greater than one standard error in the second half of his career, one of these greater than two standard errors (age 35, 1999; age 36, 2000; age 38, 2002). In addition, his residual in 2001 was .0750, which is very close to the standard error of .0757. He was thus very close to being chosen the way the other players were. No other players were this close to being chosen.

Since there is no direct information about drug use in the data used in this paper, Table 3 can only be interpreted as showing patterns for some players that are consistent with such use, not confirming such use. The patterns do not appear strong for the three pre-1990 players: Boone, Evans, and Gehringer. For the other players, some have their large residuals spread out more than others. The most spread out are those for Gaetti, Molitor, and Surhoff. Regarding Galarraga, four of his six large residuals occurred when he was playing for Colorado (1993–1997). Walker played for Colorado between 1995 and 2003, and his four large residuals all occurred in this period. Colorado has a very hitter-friendly ball park. Regarding the results in Table 3, there are likely to be different views on which of the patterns seem most suspicious, especially depending on how one weights other information and views about the players. This is not pursued further here.

From the perspective of this paper, the unusual patterns in Table 3 do not fit the model well and thus are not encouraging for the model. On the other hand, there are only at most about 15 players out of the 441 in the sample for which this is true. Even star players like Babe Ruth, Ted Williams, Rogers Hornsby, and Lou Gehrig do not show systematic patterns. In this sense the model works well, with only a few key exceptions.

7 Comparison to Other Events

In Fair (2007) rates of decline were estimated for various athletic events and for chess. Deterioration rates were estimated from age 35 on using world records by age. Given the results in Table 1, one way to compare the present results to the earlier ones is to compute what percent is lost by age 40 in each event. For example, for OPS in line 1, the percent lost is .078 divided by the mean (.793), which is 9.8 percent. For OPB in line 1, the percent lost is .020 divided by .354, which is 5.6 percent. Finally, for ERA in line 1, the percent lost is .520 divided by 3.50, which is 14.9 percent. As discussed in Section 4, pitchers are estimated to decline more rapidly than batters.

The above three percents can be compared to the percents for the other events. This is done in Table 4. The results for the other events are taken from Table 3 in Fair (2007). Two ways of comparing the results are presented in Table 4. The first is simply to list the percent lost by age 40 for each event. The second is to take, say, the 9.8 percent at age 40 for OPS and list the age at which this percent is reached for each of the other events. This second way is done for OPS, OBP, and ERA.

It should be kept in mind that the percent declines for the other events are declines from age 35. If decline in fact starts before age 35, as it is estimated to do for baseball, then the percents for the other events are too low.[4]

The events are listed in the notes to Table 4. The rates of decline for baseball are larger than they are for the other events. For OBP, non-sprint running ("Run"), and the high jump, the results are not too far apart: 5.6 percent versus 4.1 percent and 4.5 percent, with Run and the high jump being only 2 years ahead of OBP (42 years versus 40). The rate of decline for Sprint is smaller, even smaller for the swimming events, and very small for chess. The most extreme case is ERA versus Chess1, where the 14.9 percent decline for ERA at age 40 is not reached until age 85 for chess! Remember, however, that the ERA results are based on a smaller sample than the OPS and OBP results, and so the 14.9 percent figure is less reliable than the others. Nevertheless, other things being equal, chess players do seem to have a considerable advantage over pitchers.

The estimates for the other events have the advantage of being based on age records up to very old ages, in some cases up to age 100. Because of the way professional baseball works, it is not possible to get trustworthy estimates at ages

[4]The aging estimates in Fair (2007) are not affected if decline starts before age 35. The estimates just require that decline has begun by age 35. Although the first age of decline is not estimated, for the events considered in the paper there does not appear to be much decline before age 35.

DOI: 10.2202/1559-0410.1074

Table 4
Comparison of Aging Effects Across Events

	% loss at age 40	Age at 9.8% loss	Age at 5.6% loss	Age at 14.9% loss
OPS	9.8	40		
OBP	5.6		40	
ERA	14.9			40
Sprint	3.0	51	45	59
Run	4.1	47	42	53
High Jump	4.5	46	42	51
M50	2.1	57	48	68
M100	2.5	54	46	63
M200+	1.8	59	50	64
Chess1	0.9	79	64	85
Chess2	0.8	71	63	78

Notes:
- Sprint = 100, 200, and 400 meter track.
- Run = all running except 100, 200, and 400 meter track.
- M50 = 50 meter and yard swimming events.
- M100 = 100 meter and yard swimming events.
- M200+ = all other swimming events.
- Chess1 = Chess, best rating.
- Chess2 = Chess, second best rating.

Non baseball results taken from Table 3 in Fair (2007).

much beyond 40. In events like running and swimming people of all ages can participate. An elite runner, for example, can continue to run even when he (or she) is past the age at which he has any chance of placing in the top group. There are thus many observations on performances of old elite runners. This is not true of professional baseball, where once a player is out of the top group, he is not allowed to play. (Even Roger Clemens is not likely to be playing when he is 60.) There is thus no way of estimating the rate of decline of professional baseball players beyond the age of about 40. It may be if players were allowed to play into old age, their rates of decline would not be much different from those in, say, running or the high jump, but this cannot be tested.

It is interesting to speculate why rates of decline might be larger in baseball. One possibility is that baseball skills, like fast hand/eye coordination and bat speed, decline faster than skills in the other events. Another possibility is that this reflects players' responses to the fact that once they are out of the top group they can't play.

Assume that a player has some choice of his age-performance profile. Assume in particular that he can choose curve A or B in Figure 2, where, contrary to the assumptions of the model, neither curve is quadratic after the peak-performance age. The two curves reflect a trade-off between yearly performances and decline rates. It may be, as in curve A, that a player can stay near his peak-performance value for a number of years after his peak-performance age, but at a cost of faster bodily deterioration later. An alternative strategy may be, as in curve B, not to push as hard after the peak-performance age and have a slower decline rate. If $bmin$ in Figure 2 is the minimum performance level for a player to stay in the major leagues, then the player is forced to retire at age k_1 if he chooses curve A and at age k_2 if he chooses curve B. Which curve a player chooses if he is maximizing career income depends on the wage rate paid at each performance level.

Now say that the wage rate is simply proportional to the performance measure and that curves A and B are such that the player is indifferent between them. If $bmin$ is then lowered to $bmin'$, it is clear that the player will now prefer B to A since the added area under B between k_2' and k_2 is greater than that under A between k_1' and k_1. There is thus an incentive to choose flatter age-performance profiles as the minimum performance level is lowered. If this level is lower for the other events than it is for baseball, this could explain at least part of the larger estimated decline rates for baseball.

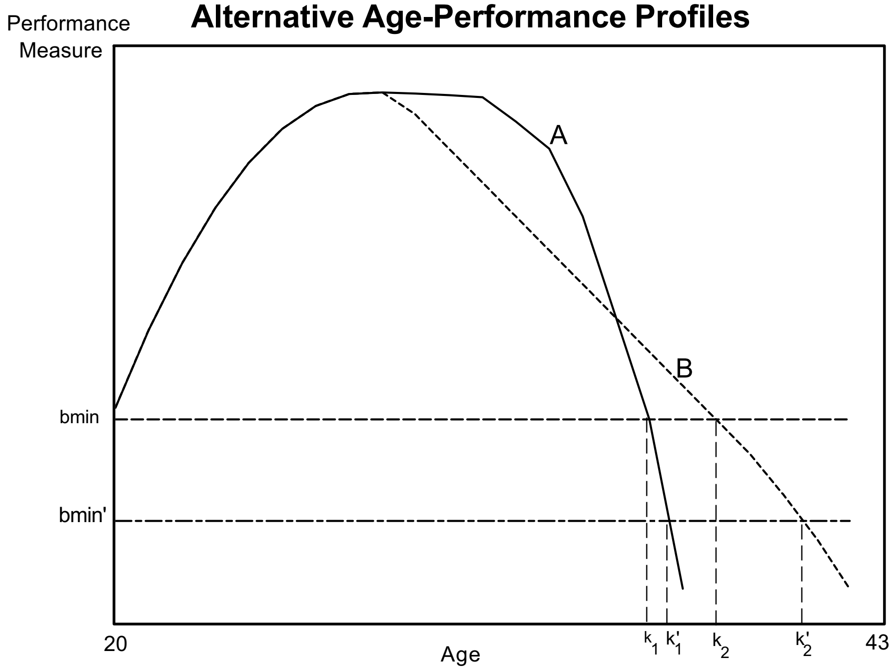
If players do have some choice over their age-performance profile, the estimates in this paper reflect this choice, although, contrary to the curves in Figure 2, the functional form is restricted to be quadratic. The assumption of the model that β_1, β_2, γ_1, γ_2, and δ are the same for all players is stronger in this case because it reflects the assumption that players all make the same choice.

8 Possible Changes Over Time

The regressions in Table 1 span a period of 84 years, a period in which a number of important changes occurred in baseball. Mention has already been made of the designated hitter rule in the American League. Another change is that beginning in the early 1970s, the reserve clause was eliminated and players got more bargaining power. Under the reserve clause, most contracts were one-year contracts, and players were required to negotiate with their current team. The main bargaining weapon of players was to hold out. After the reserve clause was eliminated, many contracts became multi year and players had more freedom to move around. This all resulted in a larger fraction of baseball revenues going to the players. There

DOI: 10.2202/1559-0410.1074

Figure 2
Alternative Age-Performance Profiles



may also have been technical progress over this period, with advances in medical procedures, increased training knowledge, and the like.

It is thus of interest to see if the coefficient estimates in Table 1 are stable over time. The sample was divided into two periods, the first consisting of players who began playing in the major leagues in 1965 or earlier and the second of those who began playing in 1966 or later. For batters, the first period consisted of 212 players and 2674 observations and the second consisted of 229 players and 2922 observations. For pitchers, there were 65 players and 807 observations in the first period and 79 players and 1002 observations in the second. The first equation for each of the three performance measures in Table 1 was tested. A χ^2 test was made of the hypothesis that the coefficients are the same in the two periods. There are 3 degrees of freedom, since 6 age coefficients are estimated instead of 3. The critical χ^2 value is 7.83 at the 95 percent confidence level and 11.34 at the 99 percent level.

For OBP the χ^2 value is 1.72, and so the stability hypothesis is not rejected. For OPS the results are somewhat sensitive to whether Barry Bonds and Mark McGwire are included. With the two included the χ^2 value is 12.72, and so the stability hypothesis is rejected at the 99 percent level. When the two are not included, the χ^2 value is 11.13, and so the stability hypothesis is rejected at the 95 percent level but not the 99 percent level. For ERA the χ^2 value is 17.15, a rejection at the 99 percent level.

The results are thus mixed, especially considering that the ERA results are less reliable because of the smaller sample sizes. It is the case, however, that the estimates using the second period only imply lower decline rates than those in Table 4 for all three measures of performance. For OPS the percent loss at age 40 is 6.5 percent instead of 9.8 percent. For OBP the loss is 4.0 percent instead of 5.6 percent. For ERA the loss is 12.9 percent instead of 14.9 percent. The 4.0 percent figure for OBP is now close to the figures for Run and High Jump in Table 4: 4.1 percent and 4.5 percent.

If the decline rates in baseball are now smaller than they used to be, this could simply be due to technical progress mentioned above. If, for example, curve A in Figure 2 is shifted to the right from the peak-performance age, the cumulative decline at any given age will be smaller. This may be all that is going on. However, if, as discussed in Section 6, players have the option of choosing different age-performance profiles, an interesting question is whether the elimination of the reserve clause has led them, other things being equal, to choose a profile with a smaller decline rate? Quirk and Fort (1992, pp. 235–239) show that the salary distribution in baseball has gotten more unequal with the elimination of the reserve clause. This, however, works in the wrong direction regarding decline rates. If the

DOI: 10.2202/1559-0410.1074

relative reward to doing well has increased, this should, other things being equal, lead to players choosing curve A over curve B in Figure 2, since curve A has more years of very high performance than does curve B. So it is unclear whether the elimination of the reserve clause has anything to do with a fall in the decline rate. A related question is why teams moved in the more recent period to a five-man pitching rotation from a four-man rotation, thus possibly decreasing the decline rate for pitchers. Has this something to do with the change in structure in the 1970s? These are left as open questions. The main result here is that there is some evidence of slightly smaller decline rates in the second half of the 84-year period, but the rates are still generally larger than those for the other events.

9 Ranking of Players

As noted in the Introduction, the regressions can be used to rank players on the basis of the size of the estimated dummy variable coefficients. Each player has his own estimated constant term. The 441 batters are ranked in Table A.1, and the 144 pitchers are ranked in Table A.2. Remember that a player is in the sample if he has played 10 or more full-time years between 1921 and 2004, where "full time" is defined as 100 or more games per year for batters and 450 or more outs for pitchers. In Table A.1 batters are ranked by the size of the player constant terms in the basic OPS regression—OPS line 1 in Table 1. The constant terms are denoted "CNST." Each player's lifetime OPS is also presented for comparison purposes along with his ranking using this measure. Table A.1 also presents the player constant terms in the basic OBP regression—OBP line 1 in Table 1—and each player's lifetime OBP. In Table A.2 pitchers are ranked by the size of the player constant terms in the basic ERA regression—ERA line 1 in Table 1. Each player's lifetime ERA is also presented for comparison purposes along with his ranking using this measure.

A number of caveats are in order before discussing these tables. Baseball aficionados have strong feelings about who is better than whom, and it is important to be clear on what criterion is being used in the present ranking. First, what counts in the present ranking is the performance of a player in his full-time years, not all years. (The lifetime values also presented in the tables are for all years, not just full-time years.) Second, the present ranking adjusts for age effects. A player's dummy variable coefficient determines the position of his graph in Figure 1, and the present ranking is simply a ranking by the height of the player's graph in this figure. Lifetime values do not account for possible differences in ages played. The present ranking thus answers the following question: How good was player i

age corrected when he played full time? The population consists of players who played full time for 10 or more years between 1921 and 2004.

A useful way to think about the present ranking is to consider when a player will be ranked higher in the present ranking than in the lifetime ranking. One possibility is that his performance when he played part time was on average worse than when he played full time, possibly because he was injured. The present ranking does not use part time performances, but lifetime values do. Another possibility, focusing only on full-time years, is that he played full time much longer than average and thus played more years beyond the peak-performance age. The present ranking adjusts for this, but lifetime values do not. Therefore, whether one likes the present ranking depends on the question he or she is interested in. If one feels that performances during part-time years should count, the present ranking is not relevant. Also, of course, if one does not want to adjust for age differences, the present ranking is not relevant.

As a final point before turning to the rankings, issues like ball park differences and the designated hitter rule in the American League are more important potential problems in the ranking of players than they are in the estimation of aging effects in Table 1. Consider a pitcher who pitched his entire life in the American League under the designated hitter rule. If because of this he had on average larger ERAs than he would have had in the National League, this does not matter in the estimation of aging effects. It just means that his constant term is larger than otherwise. The assumption upon which the estimation is based is that aging effects are the same between the two leagues, not that the players' constant terms are. However, in ranking players by the size of their constant terms, it does matter if the designated hitter rule leads to larger ERAs in the American League, since the estimated constant terms are affected by this. Likewise, if a batter played in a hitter-friendly ball park his entire career, this will affect his constant term but not the estimated aging coefficients. It should thus be kept in mind that the present ranking does not take into account issues like ball park differences and the designated hitter rule and this may be important in some cases.

Turning now to Table A.1, for OPS the ranking is Babe Ruth 1 and Ted Williams 2 using both CNST and Lifetime. The order is reversed using OBP. A real winner in the table is Henry Heilmann, who ranks 8 using CNST for both OPS and OBP. The Lifetime rankings, however, are 25 and 16, respectively. Heilmann played 14 full-time years, 4 of them before 1921. It turns out that he did noticeably better beginning in 1921 (the live ball?). He is thus ranked higher using CNST than Lifetime since CNST counts only performances from 1921 on. Apparently he was a very nice person, possessing "many virtues, including loyalty, kindness,

DOI: 10.2202/1559-0410.1074

tolerance and generosity."[5]

Most of the large differences between the CNST and Lifetime rankings can be traced to the length of the player's career. For example, for OPS Ralph Kiner is ranked 19 using Lifetime but only 27 using CNST. Kiner played exactly 10 years (all full time), ages 24-33, which is below average regarding the number of years played beyond the peak-performance age (27.59 for OPS). Thus his lifetime performance is more impressive than his performance age corrected. On the other side, for OPS Carl Yastrzemski is ranked 75 using CNST but only 99 using Lifetime. Yastrzemski played 23 years, ages 22-44, all but age 42 full time, which is way above average regarding the number of years played both before and after the peak-performance age. Remember, however, that not all the differences between the CNST and Lifetime rankings are due to length-of-career differences. Some are due to the different treatments of part-time and full-time performances, where Lifetime counts part-time years and CNST does not.

There are large differences between the OPS rankings and the OBP rankings for both CNST and Lifetime. Using CNST, Manny Ramirez is 7 OPS and 15 OBP, Mark McGwire is 11 OPS and 41 OBP, Willy Mays 19 OPS and 56 OBP, Ken Griffey Jr. 20 OPS and 72 OBP, Hank Aaron 22 OPS and 87 OBP, Albert Belle 25 OPS and 121 OBP, and so on. On the other side, Edgar Martinez is 9 OBP and 17 OPS, Mickey Cochrane is 13 OBP and 45 OPS, Jackie Robinson is 23 OBP and 60 OPS, Arky Vaughan is 18 OBP and 67 OPS, Wade Boggs is 16 OBP and 82 OPS, and so on. Within OBP, the differences between CNST and Lifetime are similar to those within OPS.

Pitchers are ranked in Table A.2. Similar considerations apply here as applied for batters. Whitey Ford ranks first in both rankings. Mike Cuellar ranks 5 using CNST but 14 using Lifetime. Cuellar played 10 full-time years, ages 29-38, which is above average regarding the number of years played after the peak-performance age (26.54 for ERA). Thus, age corrected (i.e., using CNST), he looks better. Even more extreme is Phil Niekro, who ranks 10 CNST and 48 Lifetime. Niekro pitched 24 years, ages 25-48, with all but ages 25, 26, 27, 42, and 48 being full time. This is way above average regarding the number of years played after the peak-performance age, and so age correcting his performance makes a big difference. On the other side, Juan Marichal ranks 4 Lifetime but only 11 CNST. Marichal played 13 full-time years, ages 24-36, which is somewhat below average regarding the number of years played after the peak-performance age. Hal Newhouser ranks 9 Lifetime but only 18 CNST. He played 11 full-time years, ages 20-31 except for

[5] Ira Smith, *Baseball's Famous Outfielders*, as quoted in James (2001), p. 798.

age 30. Another noticeable case is Steve Rogers, who ranks 17 Lifetime but only 46 CNST. He played 11 full-time years, ages 25-35. (Sandy Koufax is not in the rankings because he played only 9 full-time years.)

Hopefully the rankings in Tables A.1 and A.2 will serve as food for thought for baseball fans.

10 Conclusion

The estimated aging effects in Table 1 are based on the sample of players who played 10 or more full-time years in the major leagues between 1921 and 2004. The peak-performance age is around 28 for batters and 26 for pitchers. The (percentage) rates of decline after the peak-performance age are greater for pitchers than for batters and greater for OPS than for OBP. Overall, the estimated rates of decline are modest, although even a small decline in a highly competitive sport like baseball can be important. Table 4 shows that the losses in baseball are larger than the losses in track and field, running, and swimming events and considerably larger than the losses in chess. The results reported in Section 8 suggest that decline rates in baseball may have decreased slightly in the more recent period. The results in Section 7 show that there are 18 batters whose performances in the second half of their careers noticeably exceed what the model predicts they should have been. All but 3 of these players played from 1990 on. It is not possible from the data used in this study to determine whether any of these performances are due to illegal drug use. From the perspective of evaluating the model used in this paper it is encouraging that there are only 18 batters out of 441 who deviate noticeably from the model's predictions.

DOI: 10.2202/1559-0410.1074

Table A.1
Ranking of Batters

	OPS				**OBP**			
	Full time & age corrected		Lifetime		Full time & age corrected		Lifetime	
	Rank	CNST	Rank	OPS	Rank	CNST	Rank	OPS
Babe Ruth	1	0.822	1	1.164	2	0.368	2	0.474
Ted Williams	2	0.756	2	1.115	1	0.371	1	0.482
Rogers Hornsby	3	0.718	6	1.010	3	0.341	5	0.434
Lou Gehrig	4	0.706	3	1.080	4	0.332	3	0.447
Barry Bonds	5	0.699	4	1.053	5	0.329	4	0.443
Jimmie Foxx	6	0.668	5	1.038	7	0.315	7	0.428
Manny Ramirez	7	0.649	7	1.010	15	0.301	14	0.411
Harry Heilmann	8	0.638	25	0.930	6	0.321	16	0.409
Frank Thomas	9	0.628	8	0.996	8	0.314	6	0.429
Jim Thome	10	0.626	10	0.979	14	0.301	15	0.410
Mark McGwire	11	0.615	9	0.982	41	0.279	36	0.394
Mickey Mantle	12	0.613	11	0.977	10	0.309	8	0.420
Stan Musial	13	0.612	13	0.976	12	0.302	11	0.417
Joe DiMaggio	14	0.606	12	0.977	30	0.283	29	0.398
Larry Walker	15	0.602	14	0.969	26	0.286	24	0.401
Mel Ott	16	0.598	17	0.947	11	0.308	13	0.414
Edgar Martinez	17	0.595	24	0.933	9	0.311	10	0.418
Johnny Mize	18	0.590	15	0.959	27	0.286	32	0.397
Willie Mays	19	0.587	20	0.941	56	0.274	62	0.384
Ken Griffey Jr.	20	0.584	22	0.937	72	0.269	85	0.377
Jeff Bagwell	21	0.582	16	0.951	21	0.293	18	0.408
Hank Aaron	22	0.578	26	0.928	87	0.265	100	0.374
Gary Sheffield	23	0.577	28	0.928	20	0.293	26	0.400
Mike Piazza	24	0.576	18	0.947	69	0.269	59	0.386
Albert Belle	25	0.570	23	0.933	121	0.256	121	0.369
Frank Robinson	26	0.561	29	0.926	45	0.277	48	0.389
Ralph Kiner	27	0.559	19	0.946	42	0.279	31	0.398
Earl Averill	28	0.558	27	0.928	40	0.279	35	0.395
Chipper Jones	29	0.557	21	0.937	32	0.283	25	0.401
Duke Snider	30	0.553	31	0.919	81	0.266	75	0.380
Al Simmons	31	0.551	33	0.915	76	0.267	74	0.380
Dick Allen	32	0.545	34	0.912	84	0.266	79	0.378
Mike Schmidt	33	0.543	35	0.907	79	0.267	72	0.380
Juan Gonzalez	34	0.542	37	0.904	240	0.234	268	0.343
Bob Johnson	35	0.539	38	0.899	38	0.280	40	0.393
Bill Terry	36	0.538	39	0.899	34	0.281	41	0.393
Mo Vaughn	37	0.532	36	0.906	86	0.265	68	0.383
Chuck Klein	38	0.530	30	0.922	113	0.259	77	0.379
Fred McGriff	39	0.529	48	0.886	85	0.266	86	0.377
Willie McCovey	40	0.528	42	0.889	92	0.263	97	0.374
Babe Herman	41	0.528	32	0.915	91	0.263	67	0.383
Rafael Palmeiro	42	0.528	43	0.889	104	0.260	106	0.372
Tim Salmon	43	0.524	47	0.886	55	0.274	55	0.386
Goose Goslin	44	0.523	46	0.887	51	0.274	53	0.387
Mickey Cochrane	45	0.521	40	0.897	13	0.302	9	0.419
Sammy Sosa	46	0.518	41	0.892	272	0.229	242	0.348
Willie Stargell	47	0.518	44	0.889	190	0.243	169	0.360
Ellis Burks	48	0.518	60	0.874	143	0.252	146	0.363
Moises Alou	49	0.517	54	0.880	135	0.253	132	0.367
Eddie Mathews	50	0.515	49	0.885	98	0.262	90	0.376

Table A.1 (continued)
Ranking of Batters

	OPS				OBP			
	Full time & age corrected		Lifetime		Full time & age corrected		Lifetime	
	Rank	CNST	Rank	OPS	Rank	CNST	Rank	OPS
Harmon Killebrew	51	0.514	50	0.884	102	0.261	92	0.376
Darryl Strawberry	52	0.513	68	0.862	164	0.247	197	0.356
Bernie Williams	53	0.513	59	0.875	53	0.274	52	0.388
Charlie Gehringer	54	0.510	51	0.884	25	0.287	21	0.404
Ryan Klesko	55	0.509	45	0.888	117	0.258	104	0.373
Paul Waner	56	0.508	57	0.878	24	0.289	20	0.404
Will Clark	57	0.508	53	0.880	66	0.270	63	0.384
Larry Doby	58	0.508	58	0.876	58	0.273	57	0.386
Gabby Hartnett	59	0.507	72	0.858	108	0.259	120	0.370
Jackie Robinson	60	0.505	52	0.883	23	0.291	17	0.409
Jack Clark	61	0.505	80	0.854	61	0.271	78	0.379
David Justice	62	0.503	56	0.878	97	0.262	84	0.378
Al Kaline	63	0.502	78	0.855	75	0.267	93	0.376
George Brett	64	0.501	76	0.857	109	0.259	122	0.369
Joe Cronin	65	0.501	75	0.857	39	0.279	46	0.390
Jose Canseco	66	0.500	63	0.867	223	0.238	216	0.353
Arky Vaughan	67	0.499	70	0.859	18	0.295	19	0.406
Jeff Heath	68	0.499	55	0.879	131	0.254	117	0.370
Norm Cash	69	0.498	67	0.862	112	0.259	99	0.374
Bill Dickey	70	0.497	62	0.868	89	0.265	70	0.382
Joe Medwick	71	0.496	64	0.867	162	0.248	153	0.362
Jim Bottomley	72	0.495	61	0.870	129	0.254	123	0.369
George Grantham	73	0.495	82	0.854	29	0.284	42	0.392
Heinie Manush	74	0.494	77	0.856	83	0.266	88	0.377
Carl Yastrzemski	75	0.493	99	0.842	63	0.270	76	0.380
Kiki Cuyler	76	0.491	69	0.860	67	0.269	54	0.386
Minnie Minoso	77	0.491	88	0.848	48	0.276	49	0.389
Andres Galarraga	78	0.490	93	0.846	226	0.237	247	0.347
Tony Gwynn	79	0.490	91	0.847	46	0.277	50	0.388
Orlando Cepeda	80	0.490	87	0.849	208	0.240	233	0.350
John Olerud	81	0.488	65	0.864	33	0.282	28	0.399
Wade Boggs	82	0.488	73	0.858	16	0.298	12	0.415
Reggie Jackson	83	0.488	95	0.846	181	0.244	202	0.356
Reggie Smith	84	0.487	79	0.855	139	0.252	134	0.366
Shawn Green	85	0.486	66	0.864	213	0.240	196	0.357
Rudy York	86	0.483	96	0.846	161	0.248	154	0.362
Jim Rice	87	0.482	81	0.854	221	0.238	224	0.352
Billy Williams	88	0.480	83	0.853	165	0.247	160	0.361
Enos Slaughter	89	0.479	107	0.835	62	0.271	71	0.382
Kent Hrbek	90	0.479	90	0.848	133	0.253	131	0.367
Fred Lynn	91	0.479	97	0.845	178	0.245	166	0.360
Eddie Murray	92	0.479	105	0.836	155	0.249	175	0.359
Rico Carty	93	0.478	110	0.833	120	0.257	124	0.369
Sid Gordon	94	0.476	98	0.843	95	0.263	89	0.377
Luis Gonzalez	95	0.476	71	0.859	147	0.250	119	0.370
Rickey Henderson	96	0.476	135	0.820	19	0.295	23	0.401
Dave Winfield	97	0.476	120	0.827	192	0.243	218	0.353
Jeff Kent	98	0.474	74	0.858	251	0.233	222	0.352
Rocky Colavito	99	0.473	89	0.848	186	0.243	177	0.359
Sam Rice	100	0.473	183	0.801	71	0.269	101	0.374

DOI: 10.2202/1559-0410.1074

Table A.1 (continued)
Ranking of Batters

	OPS				OBP			
	Full time & age corrected		Lifetime		Full time & age corrected		Lifetime	
	Rank	CNST	Rank	OPS	Rank	CNST	Rank	OPS
Ted Kluszewski	101	0.472	86	0.850	234	0.234	217	0.353
Ray Lankford	102	0.472	100	0.841	152	0.249	142	0.364
Gene Woodling	103	0.472	142	0.817	44	0.278	56	0.386
Dwight Evans	104	0.470	102	0.840	122	0.256	118	0.370
Roy Sievers	105	0.470	119	0.829	198	0.242	211	0.354
Harold Baines	106	0.470	133	0.820	154	0.249	201	0.356
Tony Lazzeri	107	0.470	92	0.846	93	0.263	73	0.380
Frank Howard	108	0.470	85	0.851	235	0.234	219	0.352
Paul Molitor	109	0.469	143	0.817	110	0.259	126	0.369
Bobby Bonds	110	0.469	123	0.824	195	0.242	214	0.353
Paul O'Neill	111	0.467	111	0.833	158	0.249	148	0.363
Roberto Clemente	112	0.467	108	0.834	176	0.245	176	0.359
Greg Luzinski	113	0.466	101	0.840	166	0.247	149	0.363
Bobby Doerr	114	0.466	126	0.823	132	0.253	159	0.362
Bob Meusel	115	0.464	84	0.852	228	0.236	199	0.356
Vic Wertz	116	0.463	109	0.833	142	0.252	141	0.364
Dante Bichette	117	0.463	106	0.835	320	0.219	309	0.336
Keith Hernandez	118	0.463	132	0.821	47	0.276	61	0.384
Andre Thornton	119	0.462	154	0.811	140	0.252	172	0.360
Joe Morgan	120	0.462	137	0.819	35	0.281	43	0.392
Ben Chapman	121	0.462	125	0.823	57	0.273	66	0.383
Kirby Puckett	122	0.461	104	0.837	183	0.244	171	0.360
Gil Hodges	123	0.461	94	0.846	220	0.239	181	0.359
Ernie Banks	124	0.461	116	0.830	341	0.215	337	0.330
Reggie Sanders	125	0.461	112	0.832	282	0.228	260	0.344
Ivan Rodriguez	126	0.461	103	0.837	245	0.233	246	0.347
Boog Powell	127	0.460	128	0.822	153	0.249	165	0.360
Yogi Berra	128	0.460	114	0.830	244	0.234	241	0.348
Rod Carew	129	0.458	129	0.822	36	0.280	39	0.393
Bing Miller	130	0.458	134	0.820	172	0.245	180	0.359
Mark Grace	131	0.457	122	0.825	70	0.269	65	0.383
Joe Judge	132	0.457	189	0.798	65	0.270	80	0.378
Ron Santo	133	0.457	121	0.826	151	0.250	151	0.362
Carlton Fisk	134	0.456	191	0.797	266	0.230	287	0.341
Bobby Bonilla	135	0.456	118	0.829	184	0.244	189	0.358
Tony Oliva	136	0.455	117	0.830	225	0.238	215	0.353
George Foster	137	0.454	138	0.818	283	0.228	295	0.339
Dixie Walker	138	0.454	136	0.820	64	0.270	69	0.383
Roberto Alomar	139	0.453	150	0.814	100	0.261	111	0.371
Barry Larkin	140	0.452	147	0.815	124	0.255	113	0.370
Luke Appling	141	0.451	188	0.798	22	0.292	27	0.399
Tony Perez	142	0.451	170	0.804	277	0.228	286	0.341
Harlond Clift	143	0.451	113	0.831	50	0.275	45	0.390
Vern Stephens	144	0.450	146	0.815	203	0.241	204	0.355
Chili Davis	145	0.450	155	0.811	160	0.248	173	0.360
Don Mattingly	146	0.450	115	0.830	216	0.239	186	0.358
Dave Parker	147	0.449	159	0.810	287	0.227	294	0.339
Ron Gant	148	0.449	173	0.803	288	0.226	312	0.336
Tino Martinez	149	0.449	141	0.817	257	0.232	256	0.345
Julio Franco	150	0.449	228	0.785	101	0.261	133	0.366

Table A.1 (continued)
Ranking of Batters

	OPS				OBP			
	Full time & age corrected		Lifetime		Full time & age corrected		Lifetime	
	Rank	CNST	Rank	OPS	Rank	CNST	Rank	OPS
Ernie Lombardi	151	0.449	139	0.818	182	0.244	187	0.358
Elmer Valo	152	0.448	213	0.790	17	0.296	30	0.398
Johnny Bench	153	0.448	140	0.818	279	0.228	281	0.342
Joe Adcock	154	0.448	130	0.822	313	0.221	302	0.337
Vinny Castilla	155	0.447	151	0.813	371	0.208	367	0.324
Hal McRae	156	0.447	168	0.805	206	0.240	228	0.351
Bob Watson	157	0.446	156	0.811	136	0.253	144	0.363
Andre Dawson	158	0.446	167	0.805	352	0.212	368	0.323
Ken Singleton	159	0.445	124	0.824	68	0.269	51	0.388
Matt Williams	160	0.444	169	0.805	381	0.205	390	0.317
Frankie Frisch	161	0.444	182	0.801	107	0.259	127	0.369
Dale Murphy	162	0.443	148	0.815	259	0.231	253	0.346
Andy Pafko	163	0.443	185	0.799	215	0.240	232	0.350
Tim Raines	164	0.443	157	0.810	60	0.271	60	0.385
Joe Gordon	165	0.443	127	0.823	212	0.240	192	0.357
Cesar Cedeno	166	0.443	212	0.790	196	0.242	251	0.346
Craig Biggio	167	0.442	160	0.807	106	0.260	102	0.373
Bob Elliott	168	0.441	149	0.815	105	0.260	95	0.375
Joe Torre	169	0.441	144	0.817	159	0.249	139	0.365
Joe Vosmik	170	0.440	163	0.807	115	0.258	125	0.369
Del Ennis	171	0.439	153	0.812	289	0.226	292	0.340
Cecil Cooper	172	0.438	175	0.802	303	0.223	305	0.337
Jeff Conine	173	0.438	184	0.799	233	0.235	239	0.348
Carl Furillo	174	0.438	152	0.813	219	0.239	205	0.355
Brian Downing	175	0.438	195	0.796	111	0.259	116	0.370
Jimmy Wynn	176	0.437	181	0.801	130	0.254	136	0.365
Lonnie Smith	177	0.437	207	0.791	90	0.264	110	0.371
Wally Joyner	178	0.436	180	0.802	149	0.250	152	0.362
Pete Rose	179	0.436	230	0.784	80	0.267	94	0.375
Ken Boyer	180	0.435	158	0.810	256	0.232	238	0.349
Mickey Vernon	181	0.435	220	0.787	148	0.250	184	0.359
Rusty Staub	182	0.434	203	0.793	137	0.253	150	0.362
Gary Matthews	183	0.434	177	0.802	145	0.250	143	0.364
Greg Vaughn	184	0.433	162	0.807	322	0.219	303	0.337
Rick Monday	185	0.432	172	0.804	170	0.246	162	0.361
Bobby Murcer	186	0.432	179	0.802	179	0.245	190	0.357
Bobby Grich	187	0.432	200	0.794	118	0.258	114	0.370
Phil Cavarretta	188	0.431	217	0.788	94	0.263	105	0.372
Brady Anderson	189	0.431	219	0.787	144	0.251	155	0.362
Darrell Evans	190	0.431	204	0.792	163	0.247	161	0.361
Dom DiMaggio	191	0.431	178	0.802	74	0.268	64	0.383
Al Oliver	192	0.430	199	0.795	254	0.232	262	0.344
Bobby Higginson	193	0.430	145	0.816	207	0.240	179	0.359
Kenny Lofton	194	0.430	194	0.797	116	0.258	108	0.372
Richie Hebner	195	0.430	210	0.790	205	0.241	221	0.352
Garret Anderson	196	0.430	165	0.806	345	0.214	344	0.329
Robin Ventura	197	0.429	166	0.806	174	0.245	156	0.362
Pie Traynor	198	0.429	192	0.797	157	0.249	157	0.362
Roger Maris	199	0.429	131	0.822	286	0.227	255	0.345
Sam West	200	0.428	196	0.796	127	0.255	112	0.371

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Table A.1 (continued)
Ranking of Batters

	OPS Full time & age corrected Rank	OPS Full time & age corrected CNST	OPS Lifetime Rank	OPS Lifetime OPS	OBP Full time & age corrected Rank	OBP Full time & age corrected CNST	OBP Lifetime Rank	OBP Lifetime OPS
Buddy Myer	201	0.427	198	0.795	52	0.274	47	0.389
Ryne Sandberg	202	0.426	197	0.795	269	0.230	264	0.344
Steve Finley	203	0.426	224	0.787	302	0.224	304	0.337
Joe Sewell	204	0.425	171	0.804	54	0.274	44	0.391
Pinky Higgins	205	0.425	187	0.798	126	0.255	115	0.370
Bill Madlock	206	0.425	161	0.807	171	0.246	137	0.365
George Hendrick	207	0.425	246	0.775	312	0.221	343	0.329
Bill Skowron	208	0.424	206	0.792	319	0.219	327	0.332
Bill White	209	0.424	164	0.806	247	0.233	229	0.351
J.T. Snow	210	0.424	208	0.791	168	0.246	185	0.358
Chet Lemon	211	0.423	193	0.797	210	0.240	206	0.355
Ken Griffey Sr.	212	0.423	211	0.790	191	0.243	183	0.359
Stan Hack	213	0.423	209	0.791	43	0.278	37	0.394
Earl Torgeson	214	0.422	176	0.802	73	0.268	58	0.386
Ken Caminiti	215	0.421	202	0.793	274	0.229	250	0.347
Ted Simmons	216	0.421	227	0.785	248	0.233	240	0.348
Ron Cey	217	0.421	186	0.798	232	0.235	212	0.354
Hank Bauer	218	0.421	229	0.785	250	0.233	254	0.346
Willie Horton	219	0.421	216	0.789	327	0.218	325	0.332
Lu Blue	220	0.421	174	0.803	31	0.283	22	0.402
Ben Oglivie	221	0.420	225	0.786	306	0.222	310	0.336
Cal Ripken Jr.	222	0.420	218	0.788	284	0.228	291	0.340
Jimmie Dykes	223	0.419	271	0.764	114	0.258	138	0.365
Ron Fairly	224	0.419	262	0.768	134	0.253	168	0.360
Charlie Jamieson	225	0.418	276	0.763	59	0.272	83	0.378
Marty McManus	226	0.418	221	0.787	173	0.245	191	0.357
Don Baylor	227	0.417	242	0.777	273	0.229	280	0.342
Gary Carter	228	0.417	251	0.773	300	0.224	313	0.335
Chuck Knoblauch	229	0.416	231	0.783	88	0.265	82	0.378
Travis Jackson	230	0.415	257	0.770	276	0.228	306	0.337
Lou Whitaker	231	0.415	215	0.789	146	0.250	147	0.363
Al Smith	232	0.415	222	0.787	201	0.241	188	0.358
George Kell	233	0.414	232	0.781	128	0.254	129	0.367
Bobby Thomson	234	0.413	201	0.794	348	0.214	329	0.332
Robin Yount	235	0.413	255	0.772	253	0.232	279	0.342
Andy Van Slyke	236	0.413	205	0.792	242	0.234	235	0.349
George McQuinn	237	0.413	233	0.781	187	0.243	193	0.357
Edgardo Alfonzo	238	0.412	190	0.797	197	0.242	158	0.362
Wally Moses	239	0.412	236	0.779	156	0.249	145	0.363
Travis Fryman	240	0.411	237	0.779	305	0.222	311	0.336
Steve Garvey	241	0.411	243	0.775	334	0.216	340	0.329
Dusty Baker	242	0.411	238	0.779	231	0.235	248	0.347
Amos Otis	243	0.411	261	0.768	243	0.234	270	0.343
Alan Trammell	244	0.410	264	0.767	188	0.243	226	0.351
Ray Durham	245	0.410	214	0.789	229	0.236	210	0.354
Richie Ashburn	246	0.409	240	0.778	28	0.284	33	0.396
Sam Chapman	247	0.408	234	0.780	275	0.229	277	0.343
Eric Karros	248	0.406	239	0.779	364	0.210	364	0.325
Mike Hargrove	249	0.405	223	0.787	49	0.275	34	0.396
George Bell	250	0.405	226	0.785	405	0.198	395	0.316

Table A.1 (continued)
Ranking of Batters

	OPS				OBP			
	Full time & age corrected		Lifetime		Full time & age corrected		Lifetime	
	Rank	CNST	Rank	OPS	Rank	CNST	Rank	OPS
Ruben Sierra	251	0.405	260	0.769	379	0.206	391	0.317
Johnny Callison	252	0.404	253	0.772	317	0.220	333	0.331
Jose Cruz	253	0.404	247	0.774	227	0.236	207	0.354
Ken Keltner	254	0.404	241	0.778	308	0.222	298	0.338
Frank Thomas	255	0.403	249	0.774	8	0.314	6	0.429
Joe Carter	256	0.403	256	0.771	420	0.192	421	0.306
Dave Kingman	257	0.403	235	0.779	431	0.185	428	0.302
Tony Phillips	258	0.401	274	0.763	103	0.260	98	0.374
Jay Bell	259	0.401	282	0.759	255	0.232	266	0.343
Billy Herman	260	0.401	250	0.774	138	0.252	130	0.367
Joe Kuhel	261	0.400	270	0.765	175	0.245	182	0.359
Kevin McReynolds	262	0.400	245	0.775	355	0.212	346	0.328
Brett Butler	263	0.399	294	0.753	82	0.266	87	0.377
Doug DeCinces	264	0.398	248	0.774	351	0.213	342	0.329
Eddie Yost	265	0.398	268	0.765	37	0.280	38	0.394
Graig Nettles	266	0.398	301	0.750	324	0.219	341	0.329
Gregg Jefferies	267	0.398	267	0.765	237	0.234	261	0.344
Todd Zeile	268	0.398	258	0.769	271	0.229	252	0.346
Bret Boone	269	0.397	252	0.773	354	0.212	355	0.327
Lee May	270	0.397	254	0.772	411	0.196	405	0.313
Roy White	271	0.396	272	0.764	169	0.246	170	0.360
Dan Driessen	272	0.395	265	0.767	211	0.240	200	0.356
Carlos Baerga	273	0.395	286	0.757	310	0.221	328	0.332
Tom Brunansky	274	0.395	278	0.761	332	0.216	351	0.327
Sal Bando	275	0.395	280	0.760	214	0.240	220	0.352
Claudell Washington	276	0.395	316	0.745	321	0.219	362	0.325
Harvey Kuenn	277	0.393	269	0.765	200	0.241	195	0.357
Sherm Lollar	278	0.393	283	0.759	193	0.243	194	0.357
Dave Henderson	279	0.392	289	0.756	378	0.206	379	0.320
Lou Brock	280	0.392	296	0.753	264	0.230	275	0.343
Vada Pinson	281	0.391	259	0.769	363	0.210	353	0.327
Darrell Porter	282	0.391	275	0.763	202	0.241	209	0.354
Jim Eisenreich	283	0.391	312	0.746	239	0.234	283	0.342
Gil McDougald	284	0.390	266	0.766	209	0.240	198	0.356
Larry Parrish	285	0.390	285	0.757	382	0.205	385	0.318
Rick Ferrell	286	0.389	322	0.741	77	0.267	81	0.378
Toby Harrah	287	0.388	281	0.760	150	0.250	140	0.365
Carney Lansford	288	0.387	292	0.753	236	0.234	273	0.343
Gus Bell	289	0.387	244	0.775	357	0.211	336	0.330
Lance Parrish	290	0.386	293	0.753	396	0.200	404	0.313
Buddy Bell	291	0.385	306	0.747	267	0.230	289	0.341
Lou Piniella	292	0.385	320	0.741	311	0.221	324	0.333
Billy Goodman	293	0.385	290	0.754	96	0.263	91	0.376
Eric Young	294	0.385	297	0.753	167	0.247	163	0.361
Charlie Grimm	295	0.385	325	0.738	246	0.233	285	0.341
Bob Bailey	296	0.384	300	0.750	230	0.236	244	0.347
George Scott	297	0.384	263	0.767	344	0.214	321	0.333
Tony Gonzalez	298	0.383	273	0.763	260	0.231	231	0.350
Jorge Orta	299	0.383	308	0.746	307	0.222	315	0.334
Bruce Bochte	300	0.382	287	0.756	180	0.245	167	0.360

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Table A.1 (continued)
Ranking of Batters

	OPS				OBP			
	Full time & age corrected		Lifetime		Full time & age corrected		Lifetime	
	Rank	CNST	Rank	OPS	Rank	CNST	Rank	OPS
B.J. Surhoff	301	0.380	302	0.749	318	0.219	317	0.334
Felipe Alou	302	0.380	279	0.760	368	0.208	348	0.328
Tony Fernandez	303	0.379	309	0.746	241	0.234	245	0.347
Willie Kamm	304	0.379	288	0.756	123	0.256	109	0.372
Gary Gaetti	305	0.379	321	0.741	415	0.194	417	0.308
Dave Martinez	306	0.378	339	0.730	252	0.232	284	0.341
Gee Walker	307	0.378	277	0.761	360	0.211	334	0.331
Hector Lopez	308	0.378	317	0.745	331	0.216	339	0.330
Rico Petrocelli	309	0.378	298	0.752	333	0.216	326	0.332
Pinky Whitney	310	0.377	284	0.758	290	0.226	274	0.343
Pee Wee Reese	311	0.377	319	0.743	141	0.252	135	0.366
Dick Bartell	312	0.377	307	0.747	217	0.239	203	0.355
Greg Gross	313	0.376	351	0.723	78	0.267	107	0.372
Bill Freehan	314	0.376	299	0.752	299	0.224	293	0.340
Pete Runnels	315	0.376	295	0.753	119	0.257	96	0.374
Willie Jones	316	0.375	291	0.753	296	0.225	269	0.343
Jerry Mumphrey	317	0.374	315	0.745	238	0.234	237	0.349
Lloyd Waner	318	0.374	305	0.747	224	0.238	213	0.353
Tony Cuccinello	319	0.373	327	0.737	265	0.230	271	0.343
Devon White	320	0.372	324	0.739	384	0.204	380	0.320
Bill Buckner	321	0.372	343	0.729	356	0.212	375	0.321
Delino DeShields	322	0.372	341	0.729	189	0.243	223	0.352
Elston Howard	323	0.372	304	0.749	391	0.202	374	0.322
Terry Steinbach	324	0.371	311	0.746	362	0.210	359	0.326
Chris Chambliss	325	0.371	303	0.749	326	0.218	316	0.334
Curt Flood	326	0.371	337	0.732	258	0.231	278	0.342
Alvin Dark	327	0.370	318	0.744	329	0.217	322	0.333
Dick McAuliffe	328	0.370	310	0.746	285	0.227	272	0.343
Lloyd Moseby	329	0.369	313	0.746	335	0.216	332	0.332
Tommy Davis	330	0.369	333	0.734	342	0.215	345	0.329
Roy Smalley	331	0.367	323	0.740	280	0.228	258	0.345
Marquis Grissom	332	0.366	329	0.736	392	0.201	384	0.319
Jim Fregosi	333	0.365	328	0.736	295	0.225	297	0.338
Davey Lopes	334	0.364	326	0.737	263	0.231	236	0.349
Jose Offerman	335	0.364	330	0.734	177	0.245	164	0.361
Willie McGee	336	0.363	342	0.729	314	0.220	319	0.333
Willie Randolph	337	0.363	350	0.724	99	0.262	103	0.373
Tim Wallach	338	0.362	336	0.732	395	0.200	397	0.316
Garry Maddox	339	0.361	334	0.733	386	0.203	378	0.320
Brooks Robinson	340	0.360	353	0.723	358	0.211	373	0.322
Don Money	341	0.360	331	0.734	347	0.214	349	0.328
Al Bumbry	342	0.359	356	0.721	261	0.231	267	0.343
Lonny Frey	343	0.359	332	0.734	194	0.243	178	0.359
Pete O'Brien	344	0.359	314	0.745	330	0.216	307	0.336
Bill Bruton	345	0.358	357	0.720	336	0.216	347	0.328
Willie Montanez	346	0.358	340	0.729	349	0.213	352	0.327
Doc Cramer	347	0.357	360	0.716	278	0.228	290	0.340
Deron Johnson	348	0.356	338	0.731	416	0.194	411	0.311
Willie Davis	349	0.356	352	0.723	404	0.198	408	0.311
Benito Santiago	350	0.354	354	0.722	414	0.194	419	0.307

Table A.1 (continued)
Ranking of Batters

	OPS				OBP			
	Full time & age corrected		Lifetime		Full time & age corrected		Lifetime	
	Rank	CNST	Rank	OPS	Rank	CNST	Rank	OPS
Whitey Lockman	351	0.354	335	0.732	292	0.226	282	0.342
Red Schoendienst	352	0.353	349	0.724	304	0.222	300	0.337
Jose Cardenal	353	0.352	344	0.728	340	0.216	323	0.333
Bill Doran	354	0.352	345	0.728	222	0.238	208	0.354
Ken Oberkfell	355	0.351	364	0.713	204	0.241	230	0.351
Charlie Hayes	356	0.348	363	0.714	383	0.204	392	0.316
Ed Kranepool	357	0.346	382	0.693	353	0.212	393	0.316
Jim Piersall	358	0.345	358	0.718	346	0.214	331	0.332
Tim McCarver	359	0.345	347	0.725	337	0.216	301	0.337
Phil Garner	360	0.344	366	0.711	375	0.207	370	0.323
Jim Gilliam	361	0.344	361	0.715	185	0.244	174	0.360
Ron Hunt	362	0.344	362	0.715	125	0.255	128	0.368
Al Cowens	363	0.342	355	0.722	388	0.202	383	0.319
Vic Power	364	0.342	348	0.725	413	0.195	400	0.315
Ossie Bluege	365	0.341	370	0.707	218	0.239	225	0.352
Matty Alou	366	0.340	346	0.726	297	0.225	259	0.344
Peanuts Lowrey	367	0.339	376	0.698	298	0.225	308	0.336
Mark McLemore	368	0.338	384	0.690	199	0.241	234	0.349
Nellie Fox	369	0.338	368	0.710	262	0.231	243	0.347
Denis Menke	370	0.336	365	0.713	270	0.230	276	0.343
Tommy Harper	371	0.334	359	0.717	323	0.219	296	0.338
Dave Philley	372	0.333	367	0.710	325	0.218	318	0.334
Phil Rizzuto	373	0.330	372	0.706	249	0.233	227	0.351
Omar Vizquel	374	0.329	375	0.699	291	0.226	288	0.341
Rabbit Maranville	375	0.329	420	0.658	339	0.216	386	0.318
Dick Groat	376	0.328	380	0.696	343	0.215	338	0.330
Terry Pendleton	377	0.327	371	0.707	408	0.197	398	0.316
Stan Javier	378	0.327	369	0.708	293	0.226	257	0.345
Johnny Roseboro	379	0.326	378	0.697	361	0.210	360	0.326
Willie Wilson	380	0.321	373	0.702	369	0.208	357	0.326
Joe Orsulak	381	0.321	377	0.698	370	0.208	366	0.324
Mike Scioscia	382	0.320	374	0.700	294	0.225	263	0.344
Mike Bordick	383	0.320	387	0.685	366	0.209	369	0.323
Frank White	384	0.319	399	0.675	434	0.182	436	0.293
Steve Sax	385	0.319	383	0.692	309	0.221	314	0.335
Bob Boone	386	0.318	416	0.661	376	0.206	399	0.315
Granny Hamner	387	0.318	386	0.686	417	0.192	425	0.303
Bill Virdon	388	0.317	381	0.696	397	0.200	394	0.316
Chris Speier	389	0.317	398	0.676	328	0.217	354	0.327
Paul Blair	390	0.315	390	0.684	422	0.191	426	0.302
Enos Cabell	391	0.313	396	0.677	410	0.196	418	0.308
Royce Clayton	392	0.313	391	0.684	402	0.198	406	0.312
Bob Kennedy	393	0.311	413	0.664	394	0.201	413	0.309
Dave Concepcion	394	0.310	393	0.679	365	0.209	372	0.322
Greg Gagne	395	0.309	389	0.684	429	0.186	427	0.302
Tom Herr	396	0.308	379	0.697	281	0.228	249	0.347
Clete Boyer	397	0.307	407	0.670	428	0.186	432	0.299
Scott Fletcher	398	0.307	402	0.674	316	0.220	330	0.332
Frank Bolling	399	0.307	394	0.679	403	0.198	403	0.313
Maury Wills	400	0.306	415	0.661	315	0.220	335	0.330

Table A.1 (continued)
Ranking of Batters

	OPS				OBP			
	Full time & age corrected		Lifetime		Full time & age corrected		Lifetime	
	Rank	CNST	Rank	OPS	Rank	CNST	Rank	OPS
Bill Mazeroski	401	0.303	410	0.667	427	0.187	431	0.299
Leo Cardenas	402	0.302	395	0.678	412	0.195	407	0.311
Jim Gantner	403	0.302	406	0.671	389	0.202	381	0.319
Jim Davenport	404	0.301	388	0.684	399	0.199	387	0.318
Brad Ausmus	405	0.301	392	0.680	367	0.209	361	0.326
Otis Nixon	406	0.301	419	0.658	268	0.230	265	0.344
Jim Sundberg	407	0.300	401	0.674	359	0.211	356	0.327
Ozzie Smith	408	0.299	411	0.666	301	0.224	299	0.338
Russ Snyder	409	0.298	385	0.688	390	0.202	363	0.325
Al Lopez	410	0.298	414	0.663	350	0.213	358	0.326
Lenny Harris	411	0.298	412	0.665	398	0.199	388	0.317
Tommy McCraw	412	0.297	408	0.670	424	0.190	416	0.309
Del Unser	413	0.295	397	0.677	393	0.201	382	0.319
Garry Templeton	414	0.294	403	0.673	426	0.187	423	0.304
Chico Carrasquel	415	0.294	400	0.674	338	0.216	320	0.333
Manny Trillo	416	0.294	417	0.660	387	0.202	396	0.316
Marty Marion	417	0.293	409	0.668	373	0.208	371	0.323
Tony Taylor	418	0.293	405	0.673	385	0.204	376	0.321
Billy Jurges	419	0.291	418	0.660	374	0.207	365	0.325
Tony Pena	420	0.291	404	0.673	423	0.190	415	0.309
Luis Aparicio	421	0.288	423	0.653	407	0.197	410	0.311
Hughie Critz	422	0.287	421	0.656	421	0.191	424	0.303
Derrel Thomas	423	0.287	426	0.649	377	0.206	389	0.317
Bert Campaneris	424	0.286	424	0.653	401	0.199	409	0.311
Bill Russell	425	0.282	427	0.648	406	0.198	412	0.310
Jim Hegan	426	0.281	429	0.639	432	0.184	435	0.295
Julian Javier	427	0.278	425	0.651	435	0.182	434	0.296
Cookie Rojas	428	0.276	428	0.643	418	0.192	422	0.306
Tito Fuentes	429	0.275	422	0.653	425	0.189	420	0.307
Roy McMillan	430	0.262	430	0.635	400	0.199	401	0.314
Ozzie Guillen	431	0.259	434	0.626	437	0.174	437	0.287
Aurelio Rodriguez	432	0.256	433	0.626	441	0.161	441	0.275
Larry Bowa	433	0.252	435	0.620	430	0.185	430	0.300
Freddie Patek	434	0.250	431	0.633	419	0.192	414	0.309
Don Kessinger	435	0.249	432	0.626	409	0.197	402	0.314
Leo Durocher	436	0.244	436	0.619	433	0.184	433	0.298
Alfredo Griffin	437	0.233	438	0.604	439	0.170	438	0.285
Bud Harrelson	438	0.231	437	0.616	372	0.208	350	0.327
Tim Foli	439	0.225	439	0.593	438	0.171	439	0.283
Ed Brinkman	440	0.210	440	0.580	440	0.165	440	0.280
Mark Belanger	441	0.200	441	0.580	436	0.181	429	0.300

Table A.2
Ranking of Pitchers

	ERA			
	Full time & age corrected		Lifetime	
	Rank	CNST	Rank	ERA
Whitey Ford	1	4.692	1	2.745
Tom Seaver	2	4.694	3	2.862
Bob Gibson	3	4.696	5	2.915
Jim Palmer	4	4.741	2	2.856
Mike Cuellar	5	4.815	14	3.138
Lefty Grove	6	4.835	10	3.058
Warren Spahn	7	4.873	12	3.086
Gaylord Perry	8	4.874	13	3.105
Greg Maddux	9	4.886	7	2.949
Phil Niekro	10	4.887	48	3.351
Juan Marichal	11	4.897	4	2.889
Carl Hubbell	12	4.906	8	2.978
Randy Johnson	13	4.927	11	3.068
Don Drysdale	14	4.932	6	2.948
Nolan Ryan	15	4.962	20	3.193
Dazzy Vance	16	4.977	27	3.240
Roger Clemens	17	4.986	18	3.181
Hal Newhouser	18	4.998	9	3.055
Dutch Leonard	19	5.029	29	3.250
Dave McNally	20	5.048	26	3.237
Luis Tiant	21	5.051	40	3.304
Tommy John	22	5.055	45	3.342
Catfish Hunter	23	5.065	31	3.256
Don Sutton	24	5.092	32	3.261
Steve Carlton	25	5.098	23	3.215
Jim Bunning	26	5.100	35	3.269
Curt Schilling	27	5.107	43	3.325
Dolf Luque	28	5.109	28	3.245
Curt Davis	29	5.123	57	3.422
Vida Blue	30	5.135	33	3.265
Kevin Brown	31	5.138	21	3.201
Bob Lemon	32	5.139	25	3.234
Bert Blyleven	33	5.141	41	3.314
Bucky Walters	34	5.152	38	3.302
Jerry Koosman	35	5.153	50	3.359
Ed Lopat	36	5.162	22	3.206
Rick Reuschel	37	5.168	51	3.373
Claude Passeau	38	5.171	42	3.319
Red Faber	39	5.176	16	3.149
Lon Warneke	40	5.199	19	3.183
Billy Pierce	41	5.199	34	3.269
John Smoltz	42	5.205	36	3.274
Joe Niekro	43	5.207	84	3.593
Dizzy Trout	44	5.219	24	3.233
Robin Roberts	45	5.221	56	3.405
Steve Rogers	46	5.221	17	3.175
Fergie Jenkins	47	5.225	44	3.338
Dwight Gooden	48	5.230	70	3.506
Eppa Rixey	49	5.251	15	3.148
Allie Reynolds	50	5.252	39	3.304

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Table A.2 (continued)
Ranking of Pitchers

	ERA			
	Full time & age corrected		Lifetime	
	Rank	CNST	Rank	ERA
Bob Feller	51	5.252	30	3.255
Claude Osteen	52	5.259	37	3.298
Charley Root	53	5.263	81	3.586
Lefty Gomez	54	5.265	47	3.344
Orel Hershiser	55	5.274	67	3.482
Jerry Reuss	56	5.287	88	3.637
Al Leiter	57	5.298	90	3.654
Bret Saberhagen	58	5.300	46	3.343
Jim Perry	59	5.302	62	3.446
Dave Stieb	60	5.313	58	3.438
Hal Schumacher	61	5.315	49	3.357
Milt Pappas	62	5.318	54	3.398
Virgil Trucks	63	5.332	53	3.385
Curt Simmons	64	5.334	76	3.543
Larry Jackson	65	5.344	55	3.401
Bob Buhl	66	5.347	78	3.545
Camilo Pascual	67	5.353	87	3.633
Burt Hooton	68	5.356	52	3.380
Tom Glavine	69	5.362	60	3.438
Ken Holtzman	70	5.369	68	3.487
Jim Kaat	71	5.373	63	3.453
Paul Derringer	72	5.373	64	3.459
Lew Burdette	73	5.374	91	3.656
Danny Darwin	74	5.376	114	3.837
Bob Welch	75	5.383	66	3.467
David Cone	76	5.396	65	3.462
Mickey Lolich	77	5.410	59	3.438
Murry Dickson	78	5.412	92	3.656
Dennis Martinez	79	5.419	97	3.697
Fernando Valenzuela	80	5.421	77	3.545
Charlie Hough	81	5.426	106	3.746
Jimmy Key	82	5.439	71	3.507
Bill Lee	83	5.467	74	3.542
Freddie Fitzsimmons	84	5.469	72	3.509
Tom Candiotti	85	5.475	103	3.732
Ted Lyons	86	5.482	94	3.668
Larry French	87	5.485	61	3.444
Early Wynn	88	5.487	75	3.542
Tommy Bridges	89	5.508	79	3.573
Rick Rhoden	90	5.523	85	3.595
Herb Pennock	91	5.543	86	3.598
Bob Friend	92	5.553	80	3.584
Kevin Appier	93	5.553	105	3.738
Doyle Alexander	94	5.555	107	3.757
Waite Hoyt	95	5.560	82	3.588
Frank Tanana	96	5.580	93	3.662
Vern Law	97	5.584	109	3.766
Mike Mussina	98	5.586	83	3.593
Frank Viola	99	5.591	101	3.728
Tom Zachary	100	5.592	100	3.728

Table A.2 (continued)
Ranking of Pitchers

	ERA			
	Full time & age corrected		Lifetime	
	Rank	CNST	Rank	ERA
Doug Drabek	101	5.601	104	3.735
Rick Wise	102	5.602	96	3.687
Burleigh Grimes	103	5.613	73	3.527
Charlie Leibrandt	104	5.626	98	3.712
Bruce Hurst	105	5.628	121	3.917
Bob Forsch	106	5.629	108	3.765
Bob Knepper	107	5.650	95	3.676
Chuck Finley	108	5.663	116	3.845
Mark Langston	109	5.670	125	3.967
Red Lucas	110	5.673	99	3.721
Ned Garver	111	5.685	102	3.731
Dennis Eckersley	112	5.691	69	3.501
Jamie Moyer	113	5.718	135	4.148
Paul Splittorff	114	5.722	112	3.812
Jim Lonborg	115	5.727	118	3.857
Sam Jones	116	5.729	115	3.838
Red Ruffing	117	5.732	110	3.798
Mel Harder	118	5.734	111	3.801
Jesse Haines	119	5.756	89	3.641
David Wells	120	5.766	131	4.035
Jack Billingham	121	5.768	113	3.829
Bobo Newsom	122	5.771	127	3.984
Ron Darling	123	5.789	119	3.874
Guy Bush	124	5.790	117	3.855
Jack Morris	125	5.806	120	3.900
Danny MacFayden	126	5.860	123	3.961
Bill Gullickson	127	5.862	122	3.930
Andy Benes	128	5.888	126	3.973
Steve Renko	129	5.904	130	3.995
George Uhle	130	5.909	129	3.993
Tim Belcher	131	5.938	136	4.163
Mike Torrez	132	5.944	124	3.962
Rick Sutcliffe	133	5.968	133	4.080
Mike Hampton	134	5.974	128	3.991
Kenny Rogers	135	5.978	139	4.269
Kevin Gross	136	6.060	134	4.113
Wes Ferrell	137	6.073	132	4.039
Bump Hadley	138	6.085	138	4.244
John Burkett	139	6.104	140	4.309
Mike Moore	140	6.159	143	4.389
Earl Whitehill	141	6.227	142	4.358
Steve Trachsel	142	6.285	137	4.231
Kevin Tapani	143	6.327	141	4.347
Bobby Witt	144	6.616	144	4.834

DOI: 10.2202/1559-0410.1074

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