Estimated Age Effects in Baseball

Ray C. Fair*

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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 2023. 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 slightly larger for pitchers than for batters and larger for baseball than for other sports events and chess. There are 20 batters out of the sample of 582 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.

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)

*Cowles Foundation, Department of Economics, Yale University, New Haven, CT 06520-8281. email: ray.fair@yale.edu; website: *http://fairmodel.econ.yale.edu*. I am indebted to Danielle Catambay and Shreyas Mehta for research assistance and to John Oster and Sharon Oster for helpful comments. There was an error in equation (3) in the earlier version of this paper, which had a small effect on the estimates. This error has now been corrected. I am indebted to Manav Singh for pointing out this error.

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 1921–2023 (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 adjustments, 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 assump-

[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).

tion 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. WAR is an interesting measure, but it contains some subjective elements. Values of WAR can differ from site to site depending on various subjective assumptions.

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 20 batters out of the sample of 582 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, 2024)—I have estimated decline rates for various track and field, running, swimming, and rowing 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. They appear to be stable.

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 after the peak age. 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 582 batters and 178 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 27.49 years, with an estimated standard error of 0.18 years.

As noted above, 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:

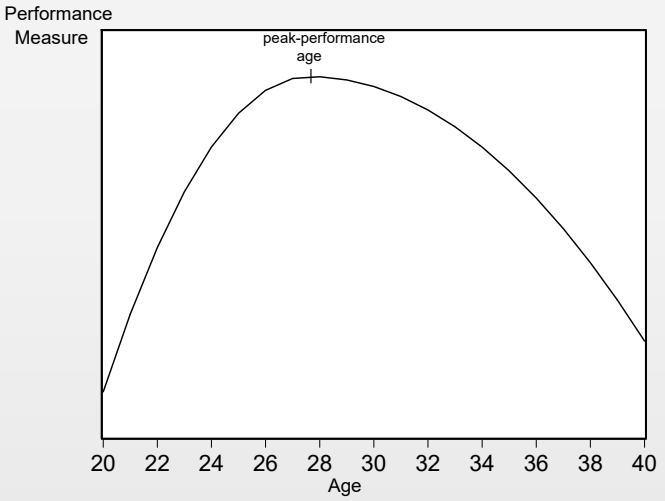
$$\begin{aligned} \beta_1 &= -2\gamma_1\delta \\ \beta_2 &= -2\gamma_2\delta \\ \alpha_{2i} &= \alpha_{1i} + (\gamma_2 - \gamma_1)\delta^2 \end{aligned} \tag{2}$$

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}.

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

[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



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:

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

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.

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 (actual minus fitted) 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 1921–2023 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 7,361 observations and 582 players, and the sample for pitchers included 2,245 observations and 178 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 in 2023 (and likely have not retired) are included in the sample if they have 10 full-time years from 2023 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 14,062 observations for 1,240 players. For pitchers the exclusion was changed to 8 years rather than 10 and 360 outs rather than 450. This gave 5,026 observations for 464 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 6,951 observations for the 582 batters and 1,995 observations for the 178 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 in parentheses. 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 for R_k and D_k

[3]This is a large nonlinear maximization problem. For the first regression for batters there are 585 coefficients to estimate: γ_1, γ_2, δ, and the 582 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 α (K coefficients to estimate). Let G' be the $K \times J$ matrix whose

Table 1
Coefficient Estimates and Implied Aging Values

	Estimate of				# obs	R_k, $[D_k]$ by age						
	γ_1	γ_2	δ	SE	(# players)	22	25	28	31	34	37	40
OPS												
1	-0.001552	-0.000599	27.49	0.0720	7361	-0.047	-0.010	0.000	-0.007	-0.025	-0.054	-0.094
	(.000040)	(.000035)	(0.18)		(582)	[2.14]	[0.97]	[-0.08]	[-0.53]	[-0.98]	[-1.43]	[-1.88]
2	-0.001619	-0.000627	27.39	0.0722	14062	-0.047	-0.009	0.000	-0.008	-0.027	-0.058	-0.100
	(.000183)	(.000035)	(0.23)		(1240)	[2.27]	[1.01]	[-0.10]	[-0.59]	[-1.08]	[-1.57]	[-2.05]
3	-0.001784	-0.000682	27.46	0.0710	6951	-0.053	-0.011	0.000	-0.009	-0.029	-0.062	-0.107
	(.000036)	(.000053)	(0.17)		(582)	[2.44]	[1.10]	[-0.09]	[-0.60]	[-1.12]	[-1.63]	[-2.14]
OBP												
1	-0.000628	-0.000176	27.66	0.0263	7361	-0.020	-0.004	0.000	-0.002	-0.007	-0.015	-0.027
	(.000015)	(.000012)	(0.17)		(582)	[2.02]	[0.95]	[-0.03]	[-0.33]	[-0.63]	[-0.93]	[-1.23]
2	-0.000655	-0.000178	27.44	0.0267	14062	-0.019	-0.004	0.000	-0.002	-0.008	-0.016	-0.028
	(.000073)	(.000012)	(0.24)		(1240)	[2.07]	[0.93]	[-0.06]	[-0.37]	[-0.68]	[-0.99]	[-1.30]
3	-0.000649	-0.000019	27.69	0.0258	6951	-0.021	-0.005	0.000	-0.002	-0.008	-0.016	-0.029
	(.000014)	(.000019)	(0.18)		(582)	[2.09]	[0.99]	[-0.03]	[-0.36]	[-0.68]	[-1.00]	[-1.32]
ERA												
1	0.009897	0.002713	26.66	0.6682	2245	0.215	0.027	0.005	0.051	0.146	0.290	0.483
	(.005195)	(.000490)	(1.02)		(178)	[-2.59]	[-0.92]	[0.20]	[0.66]	[1.11]	[1.57]	[2.03]
2	0.010952	0.002725	25.29	0.7081	5026	0.118	0.001	0.020	0.089	0.207	0.374	0.590
	(.005917)	(.000365)	(0.84)		(464)	[-1.92]	[-0.17]	[0.39]	[0.83]	[1.27]	[1.70]	[2.14]
3	0.010327	0.002234	26.35	0.6657	2245	0.196	0.019	0.006	0.048	0.131	0.253	0.416
	(.006699)	(.000838)	(1.34)		(178)	[-2.53]	[-0.79]	[0.21]	[0.58]	[0.96]	[1.34]	[1.72]

Notes:
- Standard errors are in parentheses for the coefficient estimates.
- lines 1 and 3: 10 full-time years between 1921 and 2023; full-time year: 100 games for batters, 450 outs for pitchers.
- lines 3: player observation excluded if player aged 38 or over.
- lines 2: 8 full-time years between 1921 and 2023; full-time year: 80 games for batters, 360 outs 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 0.796 OPS, line 1, 0.769 OPS, line 2, 0.798 OPS, line 3, 0.353 OBP, line 1, 0.344 OPS, line 2, 0.355 OPS, line 3, 3.57 ERA, line 1, 3.75 ERA, line 2, 3.55 ERA, line 3.

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 (not the cumulative change)..

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 7,361 and K is 585. For regression 1 for pitchers J is 2,245 and K is 181.

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 by using for pitchers 360 outs rather than 450) 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.

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 27.49 years and at age 37 the percentage rate of decline is 1.43 percent. For OBP the respective numbers are 27.66 years and 0.93 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 0.796), then the -0.054 value for R_{37} means that his predicted OPS at age 37 is 0.746, a decrease of 6.8 percent. Similarly, if a player's peak OBP is 0.350 (the mean of OBP is the sample is 0.353), then the -0.015 value for R_{37} means that his predicted OBP at age 37 is 0.335, a decrease of 4.3 percent.

For ERA δ is 26.66 and at age 37 the percentage rate of decline is 1.57 percent. If a pitcher's peak ERA is 3.50 (the mean of ERA in the sample is 3.57), then the 0.290 value for R_{37} means that his predicted ERA at age 37 is 3.79, an increase of 8.3 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 0.18 years for OPS and 0.17 years for OBP. For ERA it is 1.02 years. The sample period for pitchers is about a third the size of the period for batters, which at least partly accounts for the lower 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 582 batters used in this paper and the OBP measure. For example, there were 454 of the 582 batters who played full time when they were both 32 and 33. The average OBP for this group was 0.3580 for age 32 and 0.3340 for age 33, which is a decline of 1.13 percent. There were then 420 of the 582 batters who played full time when they were both 33 and 34. The average OBP for this group was 0.3554 for age 33 and 0.3523 for age 34, which is a decline of 0.88 percent.

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 0.63 percent for age 34, 0.93 percent for age 37, and 1.23 percent for age 40. In Table 2 the decline rate is 0.88 percent for age 34, 1.25 percent for age 37, and 3.24 percent for age 40. What can account for these large differences? A likely answer is that the delta approach

Table 2
Estimated Decline Rates Using the Delta Approach

Ages	# obs.	First Age OBP ave.	Second Age OBP ave.	% change
21–22	69	0.3421	0.3460	1.15
22–23	160	0.3418	0.3500	2.40
23–24	276	0.3489	0.3527	1.10
24–25	347	0.3483	0.3548	1.85
25–26	431	0.3518	0.3573	1.57
26–27	470	0.3560	0.3560	-0.00
27–28	496	0.3565	0.3586	0.57
28–29	500	0.3591	0.3581	-0.29
29–30	477	0.3582	0.3577	-0.13
30–31	484	0.3584	0.3593	0.24
31–32	469	0.3592	0.3571	-0.58
32–33	454	0.3580	0.3540	-1.13
33–34	420	0.3554	0.3523	-0.88
34–35	353	0.3564	0.3495	-1.93
35–36	284	0.3522	0.3472	-1.44
36–37	203	0.3524	0.3480	-1.25
37–38	133	0.3501	0.3445	-1.60
38–39	87	0.3556	0.3504	-1.45
39–40	60	0.3611	0.3494	-3.24
40–41	33	0.3484	0.3388	-2.74

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. (The error term is actual minus fitted.) 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 582 batters in the sample, there were 125 who 1) did not play in 2023 and thus were assumed to be retired, 2) the last year played was a full time year, and 3) the second-to-last year was a full time year. The average of the error terms for the last year played for each of these players, using the error terms for the OBP regression in Table 1, line 1, is -0.01727, which is smaller than the average of the error terms for the second-to-last observation of -0.00706. So this is evidence that players on average do not do as well in their last year versus their second-to-last year, which leads 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. (Errors are actual minus predicted.) 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 (.075) were recorded. Then a player was chosen if he had four or more of these residuals from age 30 on. There were a total of 20 such 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

The most remarkable performance by far in Table 3 is that of Barry Bonds. Three of his residuals (ages 37, 38, and 40) are the largest in the sample period, and the residual at age 40 is 5.6 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 Walker has three residuals that are larger than two standard errors (age 31, 1997; age 33, 1999, age 35, 2001). And Julio Franco also has three residuals that are larger than two standard errors (age 45, 2003, age 46, 2004, and age 47, 2005). Aside from the players just mentioned, nine other players have one residual greater than two standard errors: Jose Bautista (age 31, 2011), Ken Caminiti (age 33, 1996), Chili Davis (age 34, 1994), Dwight Evans (age 36, 1987), Gary Gaetti

Table 3
Age-Performance Results for
Twenty Players: OPS

Year	Age	Pred.	Act.	Resid.
Jose Bautista				
2006	26	0.847	0.755	-0.092
2007	27	0.850	0.753	-0.097
2008	28	0.850	0.718	-0.132
2009	29	0.849	0.757	-0.092
2010	30	0.847	0.995	**0.148**
2011	31	0.843	1.056	**0.212**
2013	33	0.832	0.856	0.024
2014	34	0.825	0.928	**0.103**
2015	35	0.817	0.913	**0.096**
2016	36	0.807	0.817	0.010
2017	37	0.796	0.674	-0.122
2018	38	0.784	0.727	-0.057
Barry Bonds				
1986	22	1.048	0.746	-0.302
1987	23	1.064	0.821	-0.243
1988	24	1.076	0.859	-0.218
1989	25	1.086	0.777	-0.309
1990	26	1.092	0.970	-0.122
1991	27	1.095	0.924	-0.171
1992	28	1.095	1.080	-0.016
1993	29	1.094	1.136	0.041
1994	30	1.092	1.073	-0.019
1995	31	1.088	1.009	-0.080
1996	32	1.083	1.076	-0.008
1997	33	1.077	1.031	-0.046
1998	34	1.070	1.047	-0.023
1999	35	1.062	1.006	-0.055
2000	36	1.052	1.127	**0.075**
2001	37	1.041	1.379	**0.337**
2002	38	1.029	1.381	**0.351**
2003	39	1.016	1.278	**0.262**
2004	40	1.002	1.422	**0.420**
2006	42	0.969	0.999	0.030
2007	43	0.951	1.045	**0.094**
Ken Caminiti				
1989	26	0.807	0.685	-0.122
1990	27	0.810	0.611	-0.199
1991	28	0.810	0.695	-0.115
1992	29	0.809	0.790	-0.019
1993	30	0.806	0.711	-0.095
1994	31	0.803	0.847	0.045
1995	32	0.798	0.894	**0.096**
1996	33	0.792	1.028	**0.236**
1997	34	0.785	0.897	**0.112**
1998	35	0.776	0.862	**0.086**
2001	38	0.744	0.719	-0.025

Table 3 (continued)

Year	Age	Pred.	Act.	Resid.
Chili Davis				
1982	22	0.791	0.719	-0.072
1983	23	0.807	0.657	-0.150
1984	24	0.820	0.875	0.055
1985	25	0.829	0.761	-0.068
1986	26	0.835	0.791	-0.044
1987	27	0.838	0.786	-0.052
1988	28	0.839	0.757	-0.081
1989	29	0.837	0.775	-0.062
1990	30	0.835	0.755	-0.080
1991	31	0.831	0.892	0.061
1992	32	0.827	0.825	-0.002
1993	33	0.821	0.767	-0.054
1994	34	0.813	0.971	**0.158**
1995	35	0.805	0.943	**0.138**
1996	36	0.795	0.884	**0.088**
1997	37	0.784	0.896	**0.111**
1999	39	0.759	0.812	0.053
Dwight Evans				
1973	22	0.813	0.703	-0.110
1974	23	0.829	0.756	-0.073
1975	24	0.841	0.809	-0.032
1976	25	0.851	0.755	-0.096
1978	27	0.860	0.784	-0.076
1979	28	0.860	0.820	-0.040
1980	29	0.859	0.842	-0.017
1981	30	0.857	0.937	**0.080**
1982	31	0.853	0.936	**0.082**
1983	32	0.848	0.774	-0.074
1984	33	0.842	0.920	**0.078**
1985	34	0.835	0.832	-0.003
1986	35	0.827	0.853	0.026
1987	36	0.817	0.986	**0.169**
1988	37	0.806	0.861	0.055
1989	38	0.794	0.861	0.067
1990	39	0.781	0.740	-0.041
1991	40	0.767	0.771	0.005
Steve Finley				
1990	25	0.802	0.632	-0.170
1991	26	0.808	0.737	-0.071
1992	27	0.812	0.762	-0.049
1993	28	0.812	0.689	-0.123
1995	30	0.808	0.786	-0.022
1996	31	0.805	0.885	**0.081**
1997	32	0.800	0.788	-0.012
1998	33	0.794	0.702	-0.092
1999	34	0.786	0.861	0.075
2000	35	0.778	0.904	**0.126**
2001	36	0.768	0.767	-0.001
2002	37	0.758	0.869	**0.111**
2003	38	0.746	0.863	**0.117**
2004	39	0.732	0.823	**0.091**
2005	40	0.718	0.645	-0.072
2006	41	0.702	0.714	0.012

Table 3 (continued)

Year	Age	Pred.	Act.	Resid.
Julio Franco				
1983	25	0.845	0.693	-0.151
1984	26	0.851	0.679	-0.172
1985	27	0.854	0.723	-0.131
1986	28	0.854	0.760	-0.094
1987	29	0.853	0.818	-0.035
1988	30	0.851	0.771	-0.080
1989	31	0.847	0.848	0.001
1990	32	0.842	0.785	-0.057
1991	33	0.836	0.882	0.046
1993	35	0.820	0.798	-0.022
1994	36	0.811	0.916	**0.106**
1996	38	0.788	0.877	**0.089**
1997	39	0.775	0.730	-0.045
2002	44	0.691	0.739	0.048
2003	45	0.670	0.824	**0.154**
2004	46	0.648	0.818	**0.170**
2005	47	0.626	0.799	**0.174**
Gary Gaetti				
1982	24	0.750	0.723	-0.028
1983	25	0.760	0.724	-0.036
1984	26	0.766	0.665	-0.101
1985	27	0.769	0.710	-0.060
1986	28	0.769	0.865	0.096
1987	29	0.768	0.788	0.019
1988	30	0.766	0.905	**0.139**
1989	31	0.762	0.690	-0.073
1990	32	0.757	0.650	-0.107
1991	33	0.751	0.672	-0.080
1992	34	0.744	0.610	-0.135
1993	35	0.736	0.738	0.002
1995	37	0.715	0.846	**0.131**
1996	38	0.703	0.799	**0.096**
1997	39	0.690	0.710	0.020
1998	40	0.676	0.852	**0.176**
1999	41	0.660	0.599	-0.061
Andres Galarraga				
1986	25	0.873	0.743	-0.130
1987	26	0.880	0.821	-0.059
1988	27	0.883	0.893	0.010
1989	28	0.883	0.761	-0.122
1990	29	0.882	0.715	-0.167
1991	30	0.879	0.604	-0.276
1993	32	0.871	1.005	**0.134**
1994	33	0.865	0.949	**0.084**
1995	34	0.858	0.842	-0.016
1996	35	0.849	0.958	**0.109**
1997	36	0.840	0.974	**0.134**
1998	37	0.829	0.991	**0.162**
2000	39	0.803	0.895	**0.091**
2001	40	0.789	0.784	-0.005
2002	41	0.773	0.738	-0.035
2003	42	0.757	0.841	**0.084**

Table 3 (continued)

Year	Age	Pred.	Act.	Resid.
Charlie Gehringer				
1926	23	0.867	0.721	-0.145
1927	24	0.879	0.824	-0.056
1928	25	0.889	0.846	-0.042
1929	26	0.895	0.936	0.041
1930	27	0.898	0.938	0.040
1931	28	0.898	0.790	-0.108
1932	29	0.897	0.867	-0.030
1933	30	0.895	0.862	-0.033
1934	31	0.891	0.967	**0.076**
1935	32	0.886	0.911	**0.024**
1936	33	0.880	0.987	**0.106**
1937	34	0.873	0.978	**0.104**
1938	35	0.865	0.911	0.046
1939	36	0.855	0.967	**0.112**
1940	37	0.844	0.875	0.031
1941	38	0.832	0.666	-0.166
Luis Gonzalez				
1991	24	0.848	0.753	-0.095
1992	25	0.858	0.674	-0.184
1993	26	0.864	0.818	-0.046
1994	27	0.867	0.782	-0.085
1995	28	0.868	0.812	-0.056
1996	29	0.866	0.797	-0.070
1997	30	0.864	0.722	-0.142
1998	31	0.860	0.816	-0.045
1999	32	0.856	0.952	**0.097**
2000	33	0.850	0.935	**0.086**
2001	34	0.842	1.117	**0.274**
2002	35	0.834	0.896	0.062
2003	36	0.824	0.934	**0.110**
2004	37	0.813	0.866	0.053
2005	38	0.801	0.825	0.024
2006	39	0.788	0.795	0.007
2007	40	0.774	0.793	0.019
2008	41	0.758	0.749	-0.009
Mark McGwire				
1987	24	0.984	0.987	0.003
1988	25	0.994	0.830	-0.164
1989	26	1.000	0.806	-0.194
1990	27	1.003	0.859	-0.144
1991	28	1.003	0.714	-0.290
1992	29	1.002	0.970	-0.032
1995	32	0.991	1.125	**0.134**
1996	33	0.985	1.198	**0.212**
1997	34	0.978	1.039	0.061
1998	35	0.970	1.222	**0.253**
1999	36	0.960	1.120	**0.160**

Table 3 (continued)

Year	Age	Pred.	Act.	Resid.
Paul Molitor				
1978	22	0.814	0.673	-0.141
1979	23	0.829	0.842	0.012
1980	24	0.842	0.809	-0.033
1982	26	0.858	0.816	-0.042
1983	27	0.861	0.743	-0.118
1985	29	0.860	0.764	-0.096
1986	30	0.858	0.765	-0.092
1987	31	0.854	1.003	**0.149**
1988	32	0.849	0.836	-0.014
1989	33	0.843	0.818	-0.026
1990	34	0.836	0.807	-0.029
1991	35	0.827	0.888	0.060
1992	36	0.818	0.851	0.033
1993	37	0.807	0.911	**0.104**
1994	38	0.795	0.927	**0.132**
1995	39	0.782	0.772	-0.009
1996	40	0.767	0.858	**0.091**
1997	41	0.752	0.786	0.034
1998	42	0.735	0.718	-0.017
Rafael Palmeiro				
1988	24	0.898	0.785	-0.112
1989	25	0.907	0.728	-0.180
1990	26	0.914	0.829	-0.085
1991	27	0.917	0.922	0.005
1992	28	0.917	0.786	-0.131
1993	29	0.916	0.926	0.010
1994	30	0.913	0.942	0.029
1995	31	0.910	0.963	0.053
1996	32	0.905	0.927	0.022
1997	33	0.899	0.815	-0.084
1998	34	0.892	0.945	0.053
1999	35	0.883	1.050	**0.167**
2000	36	0.874	0.954	**0.081**
2001	37	0.863	0.944	**0.081**
2002	38	0.851	0.962	**0.111**
2003	39	0.838	0.867	0.030
2004	40	0.823	0.796	-0.027
2005	41	0.808	0.786	-0.022
Ozzie Smith				
1978	24	0.670	0.623	-0.047
1979	25	0.679	0.522	-0.157
1980	26	0.685	0.589	-0.096
1981	27	0.688	0.549	-0.139
1982	28	0.689	0.653	-0.036
1983	29	0.688	0.657	-0.031
1984	30	0.685	0.684	-0.001
1985	31	0.681	0.716	0.035
1986	32	0.677	0.709	0.032
1987	33	0.671	0.775	**0.105**
1988	34	0.663	0.686	0.022
1989	35	0.655	0.696	0.041
1990	36	0.645	0.635	-0.011
1991	37	0.635	0.747	**0.112**
1992	38	0.623	0.708	**0.086**
1993	39	0.609	0.693	**0.084**

Table 3 (continued)

Year	Age	Pred.	Act.	Resid.
Sammy Sosa				
1990	22	0.844	0.687	-0.157
1991	23	0.860	0.576	-0.284
1993	25	0.882	0.794	-0.088
1994	26	0.888	0.884	-0.004
1995	27	0.891	0.840	-0.051
1996	28	0.891	0.888	-0.004
1997	29	0.890	0.779	-0.111
1998	30	0.888	1.024	**0.136**
1999	31	0.884	1.002	**0.118**
2000	32	0.879	1.040	**0.161**
2001	33	0.873	1.174	**0.301**
2002	34	0.866	0.993	**0.127**
2003	35	0.858	0.911	0.054
2004	36	0.848	0.849	0.001
2005	37	0.837	0.671	-0.166
2007	39	0.812	0.779	-0.033
Willie Stargell				
1963	23	0.875	0.717	-0.158
1964	24	0.888	0.805	-0.083
1965	25	0.897	0.829	-0.068
1966	26	0.904	0.962	0.058
1967	27	0.907	0.831	-0.076
1968	28	0.907	0.757	-0.150
1969	29	0.906	0.938	0.032
1970	30	0.903	0.839	-0.064
1971	31	0.900	1.026	**0.126**
1972	32	0.895	0.930	0.035
1973	33	0.889	1.038	**0.149**
1974	34	0.882	0.944	0.062
1975	35	0.873	0.891	0.018
1976	36	0.864	0.797	-0.067
1978	38	0.841	0.949	**0.108**
1979	39	0.827	0.904	**0.077**
B. J. Surhoff				
1987	23	0.737	0.773	0.035
1988	24	0.750	0.611	-0.139
1989	25	0.759	0.626	-0.133
1990	26	0.766	0.706	-0.059
1991	27	0.769	0.691	-0.078
1992	28	0.769	0.635	-0.134
1993	29	0.768	0.709	-0.059
1995	31	0.762	0.870	**0.108**
1996	32	0.757	0.834	**0.077**
1997	33	0.751	0.803	0.052
1998	34	0.744	0.789	0.045
1999	35	0.735	0.839	**0.104**
2000	36	0.726	0.787	0.061
2001	37	0.715	0.726	0.011
2004	40	0.675	0.785	**0.110**

Table 3 (continued)

Year	Age	Pred.	Act.	Resid.
Greg Vaughn				
1990	25	0.811	0.712	-0.100
1991	26	0.818	0.774	-0.043
1992	27	0.821	0.723	-0.098
1993	28	0.821	0.850	0.029
1995	30	0.817	0.725	-0.092
1996	31	0.814	0.903	**0.090**
1997	32	0.809	0.716	-0.093
1998	33	0.803	0.960	**0.157**
1999	34	0.796	0.881	**0.086**
2000	35	0.787	0.864	**0.077**
2001	36	0.778	0.766	-0.012
Larry Walker				
1990	24	0.969	0.761	-0.209
1991	25	0.979	0.807	-0.172
1992	26	0.985	0.859	-0.126
1993	27	0.988	0.841	-0.148
1994	28	0.989	0.981	-0.007
1995	29	0.987	0.988	0.001
1997	31	0.981	1.172	**0.191**
1998	32	0.976	1.075	**0.098**
1999	33	0.970	1.168	**0.198**
2001	35	0.955	1.111	**0.156**
2002	36	0.945	1.023	**0.078**
2003	37	0.934	0.898	-0.037
2005	39	0.909	0.886	-0.023

Notes:
- 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 .075.

(age 40, 1998), Andres Galarraga (age 37, 1998), Luis Gonzalez (age 34, 2001), Rafael Palmeiro (age 35, 1999), and Greg Vaughn (age 33, 1998).

There are only three players in Table 3 who did not play more than half their careers in the 1990s and beyond: Dwight Evans (1973–1991), Charlie Gehringer (1926–1941), and Willie Stargeil (1963–1979).. Remember that the period searched was 1921–2023, 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. Palmeiro's pattern looks similiar to that of many of the others in the table. He has four residuals greater than one standard error in the second half of his career, one of these greater than two standard errors (age 35, 1999).

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: Evans, Gehringer, and Stargell. For the other players, some have their large residuals spread out more than others. The most spread out are those for Gaetti 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. It is interesting to

note, however, that except for Jose Bautista there is no player who played from 2009 on (through 2023) who is on this list. If there was a steroid problem, it does not appear to have persisted.

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 20 players out of the 582 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 (2024) rates of decline are estimated for various athletic events. Decline rates are estimated from age 30 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 0.094 divided by the mean (0.796), which is 11.8 percent. For OPB in line 1, the percent lost is 0.027 divided by 0.353, which is 7.6 percent. Finally, for ERA in line 1, the percent lost is 0.486 divided by 3.570, which is 13.6 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 Fair (2024) except for the high jump and chess, which are taken from Fair (2007). Two ways

Table 4
Comparison of Aging Effects Across Events

	% loss at age 40	Age at 11.8% loss	Age at 7.6% loss	Age at 13.6% loss
OPS	11.8	40		
OBP	7.6		40	
ERA	13.6			40
5K	5.3	47	42	49
Marathon	3.4	48	45	50
High Jump	4.5	48	43	50
M50	3.8	55	47	58
M1500	5.5	51	44	54
ROW	2.5	59	50	62
Chess	0.9	81	74	83

Notes:
- 5K = 5 kilometers road.
- Marathon = marathon road.
- M50 = 50 meters swimming.
- M1500 = 1500 meters swimming.
- ROW = 1000-10000 meter rowing.
- Chess = Chess, best rating.
- See Fair (2007, 2024).

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 11.8 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.

The events are listed in the notes to Table 4. The main result is that the rates of decline for baseball are all larger than they are for the other events. The most extreme case is ERA versus Chess, where the 13.6 percent decline for ERA at age 40 is not reached until age 83 for chess! The closest two comparisons are OBP

versus Run 5K and OBP versus Swim 1500M. The OPB decline by age 40 is 7.6 percent versus 5.8 percent for Run 5K and 5.5 percent for Swim 1500M.

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 much beyond 40. In events like running 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. There is thus no way of estimating the rate of decline of professional baseball players beyond the age of about 40.

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.

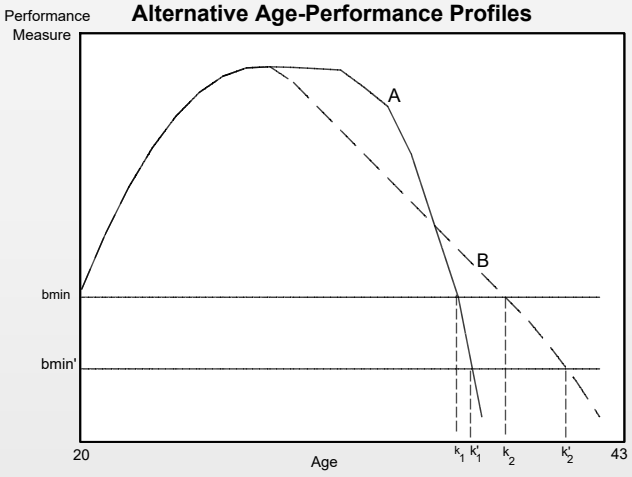
Now say that the wage rate is simply proportional to the performance measure and that curves A and B are such that the player is indifferent between them. If $bmin$ is then lowered to $bmin'$, it is clear that the player will now prefer B to A since the added area under B between k_2' and k_2 is greater 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 104 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

Figure 2
Alternative Age-Performance Profiles



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 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. To do this, 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 211 players and 2,662 observations and the second consisted of 371 players and 4,699 observations. For pitchers, there were 71 players and 889 observations in the first period and 107 players and 1,356 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 and OPS the χ^2 values were 0.21 and 5.69, respectively, and so the stability hypothesis is not rejected. For ERA the χ^2 value was 10.63, a rejection at the 95 but not 99 percent level. There is thus little evidence of instability. In the separate estimates for the two periods, there is slightly less decline by age 40 in the second period for both OBP and OPS, although, as just noted, the differences

are not significant. For ERA there is slightly more decline by age 40, 13.5 percent versus 14.9 percent.

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 582 batters are ranked in Table A.1, and the 178 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 2023, 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 2023.

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 OPS and 6 using CNST for OBP. The Lifetime rankings, however, are 26 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, tolerance and generosity."[4]

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 38 using CNST but 19 using Lifetime. Kiner played exactly 10 years (all

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

full time), ages 24-33, which is below average regarding the number of years played beyond the peak-performance age (27.49 for OPS). Thus his lifetime performance is more impressive than his performance age corrected. On the other side, for OPS Carl Yastrzemski is ranked 89 using CNST but only 132 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 12 OPS and 48 OBP; Willy Mays 20 OPS and 58 OBP; Ken Griffey Jr. 37 OPS and 122 OBP; Hank Aaron 23 OPS and 94 OBP; Albert Belle 29 OPS and 147 OBP; and so on. On the other side, Edgar Martinez is 8 OBP and 16 OPS; Mickey Cochrane is 14 OBP and 65 OPS; Jackie Robinson is 25 OBP and 75 OPS; Arky Vaughan is 21 OBP and 93 OPS; Wade Boggs is 17 OBP and 107 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. The top 5 pitchers ranked by CNST are Clayton Kershaw, Pedro Martinez, Whitey Ford, tom Seaver, and Bob Gibson. Kershaw ranks first for both CNST and Lifetime. Ford is 3 CNST and 2 Lifetime. Martinez is only ranked 7 Lifetime. Martinez played 11 years between ages 24 and 34. He did better in

the second half of his career than in the first (at the older ages), which led him to rank better age corrected. Mike Cuellar ranks 7 using CNST but 15 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 (26.66 for ERA). Thus, age corrected (i.e., using CNST), he looks better. Even more extreme is Phil Niekro, who ranks 14 CNST and 51 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 5 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 10 Lifetime but only 16 CNST. He played 11 full-time years, ages 20-31 except for age 30. Another noticeable case is Steve Rogers, who ranks 20 Lifetime but only 53 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 2023. The peak-performance age is around 27.5 for batters and 26.5 for pitchers. The

(percentage) rates of decline after the peak-performance age are slightly 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 other sports events and in chess. The results in Section 7 show that there are 20 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 20 batters out of 582 who deviate noticeably from the model's predictions.

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	0.040	1	1.164	2	0.009	2	0.474
Ted Williams	2	-0.025	2	1.116	1	0.013	1	0.482
Rogers Hornsby	3	-0.068	6	1.010	3	-0.019	5	0.434
Barry Bonds	4	-0.077	4	1.051	4	-0.025	4	0.444
Lou Gehrig	5	-0.080	3	1.080	5	-0.029	3	0.447
Jimmie Foxx	6	-0.119	5	1.038	7	-0.046	6	0.428
Manny Ramirez	7	-0.144	7	0.996	15	-0.059	15	0.411
Harry Heilmann	8	-0.146	26	0.930	6	-0.038	16	0.410
Jim Thome	9	-0.159	15	0.956	18	-0.062	25	0.402
Frank Thomas	10	-0.165	12	0.974	10	-0.052	9	0.419
Stan Musial	11	-0.169	11	0.976	12	-0.056	11	0.417
Mark McGwire	12	-0.169	8	0.982	48	-0.081	43	0.394
Mickey Mantle	13	-0.172	10	0.977	9	-0.051	7	0.421
Joe DiMaggio	14	-0.179	9	0.977	34	-0.077	32	0.398
Larry Walker	15	-0.184	13	0.965	31	-0.074	29	0.400
Edgar Martinez	16	-0.185	23	0.933	8	-0.047	10	0.418
Mel Ott	17	-0.189	18	0.947	11	-0.053	14	0.414
Todd Helton	18	-0.194	16	0.953	16	-0.060	13	0.414
Johnny Mize	19	-0.194	14	0.959	33	-0.074	36	0.397
Willie Mays	20	-0.196	21	0.941	58	-0.086	72	0.384
Alex Rodriguez	21	-0.202	28	0.930	64	-0.087	86	0.380
Jeff Bagwell	22	-0.203	17	0.948	23	-0.067	19	0.408
Hank Aaron	23	-0.206	30	0.928	94	-0.094	116	0.374
David Ortiz	24	-0.206	25	0.931	83	-0.092	85	0.380
Joey Votto	25	-0.209	35	0.920	13	-0.056	18	0.409
Lance Berkman	26	-0.209	20	0.943	26	-0.069	20	0.406
Jason Giambi	27	-0.211	38	0.916	24	-0.068	31	0.399
Chipper Jones	28	-0.215	27	0.930	28	-0.072	27	0.401
Albert Belle	29	-0.215	22	0.933	147	-0.104	144	0.369
Albert Pujols	30	-0.218	37	0.918	111	-0.097	121	0.374
Gary Sheffield	31	-0.223	46	0.907	30	-0.073	46	0.393
Frank Robinson	32	-0.223	32	0.926	53	-0.083	56	0.389
Mike Piazza	33	-0.223	34	0.922	110	-0.097	106	0.377
Carlos Delgado	34	-0.224	29	0.929	84	-0.092	74	0.383
Vladimir Guerrero	35	-0.225	24	0.931	107	-0.096	92	0.379
Earl Averill	36	-0.225	31	0.928	45	-0.080	40	0.395
Ken Griffey	37	-0.226	45	0.907	122	-0.099	137	0.370
Ralph Kiner	38	-0.227	19	0.946	51	-0.082	33	0.398
Duke Snider	39	-0.233	36	0.919	97	-0.094	89	0.380
Al Simmons	40	-0.234	40	0.915	90	-0.093	88	0.380
Bryce Harper	41	-0.237	42	0.912	43	-0.080	50	0.391
Jim Edmonds	42	-0.238	49	0.903	109	-0.097	107	0.376
Mike Schmidt	43	-0.240	43	0.908	89	-0.093	87	0.380
Dick Allen	44	-0.241	41	0.912	102	-0.095	95	0.378
Miguel Cabrera	45	-0.242	52	0.901	67	-0.088	80	0.382
Bob Johnson	46	-0.242	53	0.899	41	-0.079	45	0.393
Juan Gonzalez	47	-0.245	48	0.904	313	-0.127	344	0.343
Bill Terry	48	-0.245	54	0.899	38	-0.078	47	0.393
Brian Giles	49	-0.247	51	0.902	32	-0.074	28	0.400
Paul Goldschmidt	50	-0.249	44	0.907	71	-0.088	58	0.388

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
Fred McGriff	51	-0.254	61	0.886	95	-0.094	105	0.377
Mo Vaughn	52	-0.254	47	0.906	100	-0.095	79	0.383
Willie McCovey	53	-0.254	58	0.889	104	-0.096	118	0.374
Chuck Klein	54	-0.254	33	0.922	135	-0.101	94	0.379
Rafael Palmeiro	55	-0.256	64	0.885	127	-0.100	134	0.371
Babe Herman	56	-0.258	39	0.915	112	-0.098	78	0.383
Moises Alou	57	-0.259	62	0.885	139	-0.102	142	0.369
Tim Salmon	58	-0.261	67	0.884	62	-0.087	68	0.385
J. D. Martinez	59	-0.262	77	0.874	264	-0.121	287	0.350
Freddie Freeman	60	-0.262	50	0.902	76	-0.090	57	0.388
Goose Goslin	61	-0.263	60	0.887	59	-0.086	62	0.387
Nelson Cruz	62	-0.264	100	0.856	285	-0.123	339	0.343
Ellis Burks	63	-0.266	76	0.874	168	-0.108	177	0.363
Willie Stargell	64	-0.266	59	0.889	232	-0.117	202	0.360
Mickey Cochrane	65	-0.267	55	0.897	14	-0.059	8	0.419
Ryan Braun	66	-0.269	56	0.891	250	-0.119	223	0.358
Harmon Killebrew	67	-0.270	66	0.884	124	-0.099	110	0.376
Eddie Mathews	68	-0.270	63	0.885	116	-0.098	111	0.376
Magglio Ordonez	69	-0.274	80	0.871	145	-0.104	151	0.369
Darryl Strawberry	70	-0.274	91	0.862	206	-0.114	237	0.357
Charlie Gehringer	71	-0.274	65	0.884	29	-0.073	22	0.404
Matt Holliday	72	-0.275	57	0.889	138	-0.102	93	0.379
Paul Waner	73	-0.276	72	0.878	27	-0.070	23	0.404
Gabby Hartnett	74	-0.277	97	0.858	133	-0.100	138	0.370
Jackie Robinson	75	-0.277	68	0.883	25	-0.068	17	0.409
Larry Doby	76	-0.278	75	0.876	65	-0.087	65	0.386
Will Clark	77	-0.278	69	0.880	81	-0.091	69	0.384
Norm Cash	78	-0.278	90	0.862	117	-0.098	117	0.374
Jack Clark	79	-0.281	106	0.854	75	-0.089	90	0.379
Sammy Sosa	80	-0.281	73	0.878	368	-0.135	324	0.344
David Justice	81	-0.282	71	0.878	115	-0.098	99	0.378
George Brett	82	-0.282	98	0.857	130	-0.100	146	0.369
Al Kaline	83	-0.282	103	0.855	85	-0.092	109	0.376
J. D. Drew	84	-0.283	78	0.873	93	-0.093	70	0.384
Bobby Abreu	85	-0.284	81	0.870	42	-0.079	39	0.395
Joe Cronin	86	-0.285	99	0.857	47	-0.081	53	0.390
Jose Canseco	87	-0.286	86	0.867	283	-0.123	267	0.353
Scott Rolen	88	-0.287	105	0.855	148	-0.105	173	0.364
Carl Yastrzemski	89	-0.287	132	0.841	70	-0.088	91	0.379
Jeff Heath	90	-0.288	70	0.879	162	-0.107	139	0.370
Bernie Williams	91	-0.288	95	0.858	92	-0.093	83	0.381
Jorge Posada	92	-0.288	119	0.848	118	-0.098	120	0.374
Arky Vaughan	93	-0.289	93	0.859	21	-0.066	21	0.406
Bill Dickey	94	-0.289	85	0.868	106	-0.096	81	0.382
Giancarlo Stanton	95	-0.289	74	0.878	326	-0.129	292	0.349
Jim Bottomley	96	-0.290	83	0.869	156	-0.106	145	0.369
Andres Galarraga	97	-0.290	123	0.846	266	-0.121	309	0.347
Nolan Arenado	98	-0.290	79	0.871	351	-0.132	329	0.343
Joe Medwick	99	-0.290	87	0.867	198	-0.113	190	0.362
Kiki Cuyler	100	-0.291	92	0.860	78	-0.090	64	0.386

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
Heinie Manush	101	-0.291	101	0.856	98	-0.094	104	0.377
George Grantham	102	-0.292	108	0.854	37	-0.077	48	0.392
Derrek Lee	103	-0.292	94	0.859	177	-0.110	166	0.365
Tony Gwynn	104	-0.293	120	0.847	52	-0.083	59	0.388
Matt Stairs	105	-0.293	153	0.832	188	-0.111	245	0.356
Edwin Encarnacion	106	-0.293	122	0.846	245	-0.118	289	0.350
Wade Boggs	107	-0.294	96	0.858	17	-0.061	12	0.415
Ryan Klesko	108	-0.294	82	0.870	154	-0.106	141	0.370
Reggie Jackson	109	-0.295	125	0.846	217	-0.115	250	0.356
Mark Teixeira	110	-0.296	84	0.869	246	-0.118	210	0.360
Orlando Cepeda	111	-0.296	115	0.849	259	-0.120	286	0.350
Minnie Minoso	112	-0.297	118	0.848	54	-0.084	54	0.389
John Olerud	113	-0.297	89	0.863	40	-0.079	34	0.398
Justin Turner	114	-0.298	162	0.829	140	-0.103	180	0.363
David Wright	115	-0.298	88	0.867	129	-0.100	112	0.376
Jeff Kent	116	-0.298	104	0.855	252	-0.120	251	0.356
Reggie Smith	117	-0.299	102	0.855	173	-0.109	158	0.366
Rudy York	118	-0.303	129	0.845	195	-0.113	185	0.362
Carlos Beltran	119	-0.303	139	0.837	282	-0.123	285	0.350
Rico Carty	120	-0.303	150	0.833	137	-0.102	147	0.369
Enos Slaughter	121	-0.303	146	0.834	72	-0.089	82	0.382
Billy Williams	122	-0.304	110	0.853	197	-0.113	191	0.361
Jim Rice	123	-0.304	109	0.854	276	-0.122	272	0.352
Sam Rice	124	-0.304	247	0.801	69	-0.088	122	0.374
Rickey Henderson	125	-0.304	189	0.820	19	-0.064	26	0.401
Eddie Murray	126	-0.305	142	0.836	181	-0.110	214	0.359
Jermaine Dye	127	-0.305	168	0.826	334	-0.130	384	0.338
Luis Gonzalez	128	-0.305	127	0.845	169	-0.108	154	0.367
Adrian Gonzalez	129	-0.305	130	0.843	205	-0.114	227	0.358
Fred Lynn	130	-0.306	128	0.845	218	-0.115	208	0.360
Dave Winfield	131	-0.306	166	0.827	225	-0.116	265	0.353
Paul Konerko	132	-0.306	133	0.841	243	-0.118	263	0.354
Sid Gordon	133	-0.307	131	0.843	108	-0.097	102	0.377
Kent Hrbek	134	-0.308	117	0.848	165	-0.108	156	0.367
Gene Woodling	135	-0.309	198	0.817	46	-0.080	63	0.386
Cliff Floyd	136	-0.311	135	0.840	199	-0.113	225	0.358
Paul Molitor	137	-0.312	200	0.817	125	-0.099	150	0.369
Andruw Jones	138	-0.312	177	0.823	321	-0.129	394	0.337
Raul Ibanez	139	-0.312	246	0.801	324	-0.129	410	0.335
Dwight Evans	140	-0.312	134	0.840	143	-0.103	136	0.370
Shawn Green	141	-0.312	113	0.850	274	-0.122	255	0.355
Rocky Colavito	142	-0.313	116	0.848	235	-0.117	212	0.359
Ted Kluszewski	143	-0.313	114	0.850	296	-0.126	270	0.353
Harold Baines	144	-0.313	187	0.820	182	-0.110	244	0.356
Ray Lankford	145	-0.313	136	0.840	187	-0.111	172	0.364
Roy Sievers	146	-0.313	163	0.829	244	-0.118	262	0.354
Aramis Ramirez	147	-0.315	149	0.833	371	-0.135	358	0.341
Frank Howard	148	-0.315	112	0.851	294	-0.126	279	0.352
Jose Altuve	149	-0.315	145	0.834	170	-0.108	168	0.364
Tony Lazzeri	150	-0.316	126	0.846	113	-0.098	84	0.380

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
Hanley Ramirez	151	-0.316	121	0.847	233	-0.117	197	0.360
Paul O'Neill	152	-0.317	152	0.833	184	-0.111	181	0.363
Bobby Bonds	153	-0.317	171	0.824	247	-0.119	266	0.353
Adam Dunn	154	-0.318	107	0.854	212	-0.115	170	0.364
Robinson Cano	155	-0.318	138	0.839	293	-0.126	280	0.351
Roberto Clemente	156	-0.318	148	0.834	216	-0.115	211	0.359
Julio Franco	157	-0.319	308	0.782	101	-0.095	163	0.365
Greg Luzinski	158	-0.320	137	0.840	207	-0.114	179	0.363
Dante Bichette	159	-0.320	143	0.835	412	-0.140	401	0.336
Joe Morgan	160	-0.320	193	0.819	39	-0.079	49	0.392
Carlton Fisk	161	-0.321	257	0.797	308	-0.127	363	0.341
Andre Thornton	162	-0.321	215	0.811	167	-0.108	199	0.360
Bob Meusel	163	-0.321	111	0.852	288	-0.124	248	0.356
Bobby Doerr	164	-0.322	176	0.823	163	-0.107	186	0.362
Andrew McCutchen	165	-0.322	144	0.835	150	-0.105	149	0.369
Jose Bautista	166	-0.322	141	0.836	211	-0.114	192	0.361
Vic Wertz	167	-0.323	151	0.833	175	-0.109	171	0.364
Reggie Sanders	168	-0.323	158	0.830	347	-0.132	342	0.343
Gil Hodges	169	-0.323	124	0.846	268	-0.121	218	0.359
Keith Hernandez	170	-0.323	184	0.821	55	-0.084	71	0.384
Ernie Banks	171	-0.323	156	0.830	444	-0.144	443	0.330
Chase Utley	172	-0.324	174	0.823	221	-0.116	224	0.358
Kirby Puckett	173	-0.325	140	0.837	234	-0.117	200	0.360
Ben Chapman	174	-0.325	175	0.823	68	-0.088	73	0.383
Tony Oliva	175	-0.325	160	0.830	275	-0.122	268	0.353
Bing Miller	176	-0.326	190	0.820	204	-0.114	220	0.359
Yogi Berra	177	-0.326	157	0.830	301	-0.127	299	0.348
Rod Carew	178	-0.326	179	0.822	44	-0.080	44	0.393
Victor Martinez	179	-0.326	207	0.815	203	-0.114	209	0.360
Javy Lopez	180	-0.326	164	0.828	406	-0.139	395	0.337
Justin Upton	181	-0.327	211	0.812	286	-0.124	352	0.342
Mark Grace	182	-0.327	170	0.825	79	-0.091	76	0.383
Tony Clark	183	-0.327	172	0.824	380	-0.136	376	0.339
Joe Judge	184	-0.327	253	0.798	77	-0.090	98	0.378
Boog Powell	185	-0.327	180	0.822	191	-0.112	195	0.361
Joe Mauer	186	-0.328	165	0.827	57	-0.086	60	0.388
Jeromy Burnitz	187	-0.328	167	0.826	366	-0.135	318	0.345
Derek Jeter	188	-0.329	197	0.817	99	-0.095	103	0.377
Dixie Walker	189	-0.329	188	0.820	74	-0.089	77	0.383
Adrian Beltre	190	-0.329	191	0.819	353	-0.133	374	0.339
Bobby Bonilla	191	-0.329	161	0.829	230	-0.116	222	0.358
Luke Appling	192	-0.329	250	0.798	22	-0.066	30	0.399
George Foster	193	-0.330	194	0.818	349	-0.132	385	0.338
Ron Santo	194	-0.330	169	0.826	186	-0.111	189	0.362
Barry Larkin	195	-0.331	204	0.815	146	-0.104	133	0.371
Buster Posey	196	-0.332	154	0.831	155	-0.106	128	0.372
Pat Burrell	197	-0.332	147	0.834	237	-0.117	193	0.361
Kevin Millar	198	-0.332	218	0.810	202	-0.114	232	0.358
Dave Parker	199	-0.333	217	0.810	350	-0.132	372	0.339
Matt Kemp	200	-0.333	185	0.821	402	-0.139	388	0.337

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
Tony Perez	201	-0.333	231	0.804	343	-0.131	365	0.341
Alfonso Soriano	202	-0.333	192	0.819	502	-0.154	515	0.319
Hal McRae	203	-0.333	230	0.805	238	-0.117	282	0.351
Roberto Alomar	204	-0.334	208	0.814	128	-0.100	129	0.371
Chili Davis	205	-0.334	214	0.811	189	-0.111	201	0.360
Tino Martinez	206	-0.335	206	0.815	320	-0.129	326	0.344
Ron Gant	207	-0.335	237	0.803	360	-0.134	400	0.336
Ernie Lombardi	208	-0.336	195	0.818	223	-0.116	230	0.358
Carlos Lee	209	-0.336	186	0.821	391	-0.137	375	0.339
Joe Adcock	210	-0.336	178	0.822	408	-0.139	387	0.337
Harlond Clift	211	-0.336	155	0.831	60	-0.087	52	0.390
Don Mattingly	212	-0.336	159	0.830	271	-0.122	231	0.358
Vern Stephens	213	-0.337	202	0.815	254	-0.120	256	0.355
Andre Dawson	214	-0.337	224	0.806	462	-0.147	492	0.323
Elmer Valo	215	-0.338	279	0.790	20	-0.064	35	0.398
Johnny Bench	216	-0.338	196	0.817	357	-0.133	347	0.342
Frankie Frisch	217	-0.339	245	0.801	132	-0.100	148	0.369
Bob Watson	218	-0.340	213	0.811	166	-0.108	169	0.364
Ken Singleton	219	-0.340	173	0.824	80	-0.091	61	0.388
Vinny Castilla	220	-0.340	256	0.797	489	-0.150	500	0.321
Craig Biggio	221	-0.340	259	0.796	158	-0.107	176	0.363
Matt Williams	222	-0.341	228	0.805	506	-0.155	521	0.317
Tim Raines	223	-0.341	219	0.810	73	-0.089	67	0.385
Brian Downing	224	-0.343	260	0.796	126	-0.099	135	0.370
Joe Gordon	225	-0.343	182	0.822	262	-0.121	236	0.357
Dale Murphy	226	-0.343	205	0.815	329	-0.129	312	0.346
Ryan Zimmerman	227	-0.343	201	0.816	374	-0.135	357	0.341
Andy Pafko	228	-0.343	248	0.799	269	-0.121	290	0.350
Bob Elliott	229	-0.343	203	0.815	131	-0.100	113	0.375
Pete Rose	230	-0.344	302	0.784	82	-0.092	114	0.375
Jeff Conine	231	-0.345	282	0.789	279	-0.122	307	0.347
Joe Torre	232	-0.345	199	0.817	192	-0.112	165	0.365
Cesar Cedeno	233	-0.345	278	0.790	248	-0.119	306	0.347
Kenny Lofton	234	-0.345	266	0.794	121	-0.099	127	0.372
Cecil Cooper	235	-0.346	236	0.803	390	-0.137	397	0.337
Lonnie Smith	236	-0.347	275	0.791	103	-0.096	131	0.371
Andre Ethier	237	-0.347	181	0.822	253	-0.120	213	0.359
Carl Furillo	238	-0.347	209	0.813	270	-0.121	254	0.355
Wally Joyner	239	-0.347	243	0.802	176	-0.110	188	0.362
Mickey Vernon	240	-0.347	291	0.787	174	-0.109	221	0.359
Joe Vosmik	241	-0.348	221	0.807	144	-0.103	143	0.369
Torii Hunter	242	-0.348	271	0.793	417	-0.140	441	0.331
Del Ennis	243	-0.348	212	0.812	370	-0.135	369	0.340
Mike Lowell	244	-0.349	229	0.805	363	-0.134	355	0.342
Jim Wynn	245	-0.349	244	0.802	160	-0.107	161	0.366
Darrell Evans	246	-0.349	274	0.792	185	-0.111	194	0.361
Ken Boyer	247	-0.350	216	0.810	319	-0.128	295	0.349
Rusty Staub	248	-0.351	270	0.793	161	-0.107	183	0.362
Greg Vaughn	249	-0.352	220	0.807	420	-0.141	392	0.337
Gary Matthews	250	-0.352	241	0.802	178	-0.110	174	0.364

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
Brady Anderson	251	-0.352	289	0.787	172	-0.109	182	0.362
Bobby Grich	252	-0.354	268	0.794	141	-0.103	130	0.371
Rick Monday	253	-0.354	233	0.804	215	-0.115	196	0.361
Al Oliver	254	-0.354	262	0.795	316	-0.128	320	0.344
Bobby Murcer	255	-0.354	240	0.802	226	-0.116	235	0.357
Curtis Granderson	256	-0.354	238	0.803	397	-0.138	399	0.337
Dom DiMaggio	257	-0.355	242	0.802	86	-0.093	75	0.383
Robin Ventura	258	-0.355	225	0.806	213	-0.115	184	0.362
Pie Traynor	259	-0.355	255	0.797	193	-0.112	187	0.362
Bobby Higginson	260	-0.356	210	0.813	255	-0.120	228	0.358
Ben Zobrist	261	-0.356	304	0.783	194	-0.112	241	0.357
Evan Longoria	262	-0.356	234	0.804	436	-0.143	426	0.333
Phil Cavarretta	263	-0.356	286	0.788	114	-0.098	124	0.372
Richie Hebner	264	-0.357	281	0.790	258	-0.120	278	0.352
Adam LaRoche	265	-0.357	254	0.798	419	-0.140	403	0.336
Michael Cuddyer	266	-0.357	227	0.805	364	-0.134	322	0.344
Roger Maris	267	-0.357	183	0.822	362	-0.134	316	0.345
Sam West	268	-0.357	261	0.796	153	-0.106	132	0.371
Ivan Rodriguez	269	-0.358	252	0.798	423	-0.141	418	0.334
Ryne Sandberg	270	-0.358	264	0.795	336	-0.130	323	0.344
Aubrey Huff	271	-0.359	226	0.806	392	-0.137	354	0.342
Buddy Myer	272	-0.359	263	0.795	61	-0.087	55	0.389
Bill Skowron	273	-0.360	272	0.792	421	-0.141	434	0.332
Joe Sewell	274	-0.360	232	0.804	63	-0.087	51	0.391
George Hendrick	275	-0.360	333	0.775	407	-0.139	457	0.329
Miguel Tejada	276	-0.360	277	0.791	394	-0.138	402	0.336
Pinky Higgins	277	-0.360	251	0.798	152	-0.106	140	0.370
Ken Griffey	278	-0.360	280	0.790	229	-0.116	217	0.359
Bill Madlock	279	-0.360	222	0.807	214	-0.115	167	0.365
Brian McCann	280	-0.361	283	0.789	384	-0.136	390	0.337
Steve Finley	281	-0.361	330	0.775	395	-0.138	430	0.332
Bill White	282	-0.362	223	0.806	312	-0.127	281	0.351
Stan Hack	283	-0.362	276	0.791	50	-0.082	41	0.394
Hank Bauer	284	-0.363	298	0.785	300	-0.127	311	0.346
Ken Caminiti	285	-0.363	265	0.794	342	-0.131	305	0.347
Jimmy Dykes	286	-0.363	365	0.764	134	-0.100	162	0.365
Chet Lemon	287	-0.363	258	0.797	260	-0.121	257	0.355
Hunter Pence	288	-0.363	267	0.794	409	-0.139	417	0.334
Ron Cey	289	-0.363	249	0.799	290	-0.125	259	0.354
Cal Ripken	290	-0.363	288	0.788	346	-0.132	367	0.340
Ben Oglivie	291	-0.363	296	0.786	393	-0.138	405	0.336
Earl Torgeson	292	-0.363	239	0.802	87	-0.093	66	0.385
Willie Horton	293	-0.364	285	0.789	433	-0.142	437	0.332
J. T. Snow	294	-0.365	303	0.784	208	-0.114	239	0.357
Ted Simmons	295	-0.365	300	0.785	310	-0.127	301	0.348
Garret Anderson	296	-0.365	297	0.785	471	-0.148	486	0.324
Charlie Jamieson	297	-0.365	370	0.763	66	-0.088	97	0.378
Lu Blue	298	-0.365	235	0.803	36	-0.077	24	0.402
Johnny Damon	299	-0.365	301	0.785	265	-0.121	275	0.352
Ron Fairly	300	-0.366	350	0.768	159	-0.107	203	0.360

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
Jay Bruce	301	-0.367	311	0.781	507	-0.155	536	0.314
Don Baylor	302	-0.367	324	0.777	340	-0.131	346	0.342
Marty McManus	303	-0.369	294	0.787	220	-0.115	238	0.357
Gary Carter	304	-0.369	339	0.773	383	-0.136	411	0.335
Ray Durham	305	-0.369	287	0.788	287	-0.124	277	0.352
Dexter Fowler	306	-0.370	331	0.775	190	-0.112	226	0.358
George McQuinn	307	-0.370	310	0.781	224	-0.116	234	0.357
Al Smith	308	-0.370	292	0.787	249	-0.119	229	0.358
Chuck Knoblauch	309	-0.371	305	0.783	105	-0.096	100	0.378
Lou Whitaker	310	-0.371	284	0.789	179	-0.110	178	0.363
Melvin Mora	311	-0.371	309	0.781	295	-0.126	288	0.350
Ichiro Suzuki	312	-0.371	385	0.757	209	-0.114	253	0.355
Carlos Santana	313	-0.371	295	0.787	277	-0.122	247	0.356
Bobby Thomson	314	-0.371	269	0.794	457	-0.147	438	0.332
Wally Moses	315	-0.372	318	0.779	183	-0.110	175	0.364
Steve Garvey	316	-0.372	332	0.775	437	-0.143	450	0.329
Robin Yount	317	-0.372	341	0.772	315	-0.128	348	0.342
George Kell	318	-0.372	313	0.781	157	-0.107	157	0.367
Travis Jackson	319	-0.372	344	0.770	356	-0.133	393	0.337
Andy Van Slyke	320	-0.373	273	0.792	309	-0.127	296	0.349
Michael Young	321	-0.373	290	0.787	344	-0.132	314	0.346
Mike Cameron	322	-0.374	307	0.782	389	-0.137	381	0.338
Dusty Baker	323	-0.374	317	0.779	292	-0.125	303	0.347
Nick Markakis	324	-0.375	312	0.781	239	-0.118	243	0.357
Amos Otis	325	-0.375	349	0.768	304	-0.127	335	0.343
Travis Fryman	326	-0.376	319	0.779	410	-0.139	408	0.336
Ian Kinsler	327	-0.377	325	0.777	385	-0.136	389	0.337
Alan Trammell	328	-0.377	354	0.767	236	-0.117	271	0.352
Sam Chapman	329	-0.377	314	0.780	345	-0.132	350	0.342
Richie Ashburn	330	-0.378	321	0.778	35	-0.077	37	0.396
Jose Cruz	331	-0.378	336	0.774	281	-0.123	260	0.354
Jason Varitek	332	-0.378	327	0.776	348	-0.132	366	0.341
Eric Karros	333	-0.379	320	0.779	485	-0.150	485	0.325
Mike Hargrove	334	-0.379	293	0.787	56	-0.085	38	0.396
Marlon Byrd	335	-0.380	380	0.759	426	-0.141	455	0.329
Ruben Sierra	336	-0.380	359	0.765	500	-0.154	532	0.315
George Bell	337	-0.380	299	0.785	542	-0.163	527	0.316
Joe Carter	338	-0.381	342	0.771	553	-0.168	559	0.306
Jose Valentin	339	-0.381	348	0.769	521	-0.158	499	0.321
Graig Nettles	340	-0.381	407	0.750	403	-0.139	451	0.329
Tony Phillips	341	-0.381	369	0.763	123	-0.099	119	0.374
Dave Kingman	342	-0.381	316	0.780	571	-0.175	566	0.302
Joe Kuhel	343	-0.382	362	0.765	201	-0.114	219	0.359
Frank Thomas	344	-0.383	334	0.774	508	-0.155	505	0.320
Brett Butler	345	-0.383	398	0.753	88	-0.093	101	0.377
Jay Bell	346	-0.383	379	0.759	317	-0.128	331	0.343
Johnny Callison	347	-0.383	338	0.773	429	-0.142	442	0.331
Ken Keltner	348	-0.384	323	0.778	411	-0.140	378	0.338
Mark Reynolds	349	-0.384	315	0.780	478	-0.149	462	0.328
Billy Herman	350	-0.384	335	0.774	171	-0.108	155	0.367

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
Vernon Wells	351	-0.385	322	0.778	527	-0.159	508	0.319
Todd Zeile	352	-0.385	347	0.769	331	-0.130	313	0.346
Doug DeCinces	353	-0.385	337	0.774	459	-0.147	452	0.329
Edgardo Alfonzo	354	-0.386	306	0.782	280	-0.122	233	0.357
Kevin McReynolds	355	-0.386	329	0.775	474	-0.149	464	0.328
Joe Randa	356	-0.387	357	0.765	365	-0.134	371	0.339
Bret Boone	357	-0.388	351	0.767	470	-0.148	484	0.325
Carl Crawford	358	-0.388	360	0.765	428	-0.142	448	0.330
Lee May	359	-0.388	340	0.772	547	-0.165	540	0.313
Eddie Yost	360	-0.389	356	0.765	49	-0.081	42	0.394
Roy White	361	-0.389	363	0.764	210	-0.114	204	0.360
Jim Eisenreich	362	-0.390	422	0.746	289	-0.124	362	0.341
Gregg Jefferies	363	-0.390	358	0.765	311	-0.127	325	0.344
Adam Jones	364	-0.390	343	0.771	523	-0.158	522	0.317
Lyle Overbay	365	-0.390	326	0.776	358	-0.133	304	0.347
Dan Driessen	366	-0.391	352	0.767	261	-0.121	249	0.356
Sal Bando	367	-0.391	377	0.760	263	-0.121	273	0.352
Sherm Lollar	368	-0.391	381	0.759	231	-0.117	242	0.357
Lou Brock	369	-0.391	397	0.753	325	-0.129	333	0.343
Carlos Baerga	370	-0.392	391	0.754	415	-0.140	428	0.332
Claudell Washington	371	-0.392	423	0.745	425	-0.141	482	0.325
Tom Brunansky	372	-0.392	375	0.761	446	-0.145	471	0.327
Harvey Kuenn	373	-0.393	361	0.765	251	-0.119	240	0.357
Dave Henderson	374	-0.393	388	0.756	501	-0.154	506	0.320
Vada Pinson	375	-0.394	345	0.769	488	-0.150	468	0.327
Rick Ferrell	376	-0.396	436	0.741	91	-0.093	96	0.378
Larry Parrish	377	-0.396	384	0.757	511	-0.156	519	0.318
Darrell Porter	378	-0.396	367	0.763	256	-0.120	258	0.354
Gil McDougald	379	-0.397	355	0.766	267	-0.121	246	0.356
Lou Piniella	380	-0.397	435	0.741	398	-0.138	421	0.333
Michael Tucker	381	-0.397	368	0.763	401	-0.139	377	0.339
Toby Harrah	382	-0.398	378	0.760	180	-0.110	164	0.365
Neil Walker	383	-0.398	364	0.764	399	-0.138	383	0.338
Eric Young	384	-0.398	411	0.749	196	-0.113	215	0.359
Jhonny Peralta	385	-0.398	402	0.752	441	-0.144	453	0.329
Gus Bell	386	-0.399	328	0.775	483	-0.150	444	0.330
Carney Lansford	387	-0.399	396	0.753	299	-0.127	327	0.343
Lance Parrish	388	-0.400	394	0.753	531	-0.161	538	0.313
Rich Aurilia	389	-0.400	371	0.762	461	-0.147	460	0.328
Buddy Bell	390	-0.401	414	0.747	338	-0.131	359	0.341
Eric Hosmer	391	-0.401	372	0.762	413	-0.140	413	0.335
Charlie Grimm	392	-0.401	444	0.738	307	-0.127	364	0.341
Billy Goodman	393	-0.402	392	0.754	120	-0.099	108	0.376
George Scott	394	-0.402	353	0.767	455	-0.146	425	0.333
Randy Winn	395	-0.402	382	0.759	372	-0.135	340	0.343
Tony Gonzalez	396	-0.402	366	0.764	328	-0.129	291	0.350
Russell Martin	397	-0.403	416	0.746	305	-0.127	298	0.349
Jorge Orta	398	-0.403	419	0.746	404	-0.139	414	0.334
Bruce Bochte	399	-0.403	386	0.756	219	-0.115	198	0.360
Gary Gaetti	400	-0.403	433	0.741	548	-0.165	555	0.308

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
Bob Bailey	401	-0.403	406	0.750	291	-0.125	302	0.347
B. J. Surhoff	402	-0.404	427	0.745	418	-0.140	439	0.332
Felipe Alou	403	-0.404	373	0.761	491	-0.151	459	0.328
DJ LeMahieu	404	-0.404	346	0.769	303	-0.127	264	0.354
Jose Reyes	405	-0.404	376	0.761	443	-0.144	419	0.334
Melky Cabrera	406	-0.405	405	0.751	414	-0.140	416	0.334
Tony Fernandez	407	-0.405	417	0.746	297	-0.127	308	0.347
Pee Wee Reese	408	-0.406	431	0.743	164	-0.107	159	0.366
Mark Loretta	409	-0.406	390	0.754	228	-0.116	207	0.360
Alex Gordon	410	-0.406	412	0.748	382	-0.136	382	0.338
Gee Walker	411	-0.406	374	0.761	477	-0.149	440	0.331
Asdrubal Cabrera	412	-0.406	401	0.752	456	-0.146	456	0.329
A. J. Pierzynski	413	-0.406	443	0.739	498	-0.154	512	0.319
Hector Lopez	414	-0.406	425	0.745	439	-0.143	445	0.330
Dave Martinez	415	-0.406	460	0.730	314	-0.128	361	0.341
Edgar Renteria	416	-0.407	434	0.741	306	-0.127	345	0.343
Willie Kamm	417	-0.407	387	0.756	149	-0.105	126	0.372
Jason Heyward	418	-0.407	408	0.749	388	-0.137	373	0.339
Pinky Whitney	419	-0.409	383	0.758	369	-0.135	337	0.343
Rico Petrocelli	420	-0.410	400	0.752	449	-0.145	429	0.332
Pete Runnels	421	-0.410	393	0.753	142	-0.103	115	0.375
Dick Bartell	422	-0.410	413	0.747	272	-0.122	252	0.355
Placido Polanco	423	-0.410	438	0.740	337	-0.130	336	0.343
Elston Howard	424	-0.410	410	0.749	517	-0.157	497	0.322
Greg Gross	425	-0.411	477	0.723	96	-0.094	125	0.372
Bill Freehan	426	-0.411	403	0.752	386	-0.136	370	0.340
Devon White	427	-0.411	442	0.739	509	-0.156	513	0.319
Willie Jones	428	-0.411	399	0.753	381	-0.136	330	0.343
Jerry Mumphrey	429	-0.411	424	0.745	298	-0.127	293	0.349
Starlin Castro	430	-0.411	457	0.732	479	-0.149	514	0.319
Bill Buckner	431	-0.411	465	0.729	467	-0.148	501	0.321
Jimmy Rollins	432	-0.412	430	0.743	490	-0.151	487	0.324
Tony Cuccinello	433	-0.412	447	0.737	339	-0.131	341	0.343
Brett Gardner	434	-0.413	437	0.740	359	-0.133	356	0.342
Terry Steinbach	435	-0.413	418	0.746	481	-0.149	477	0.326
Alex Rios	436	-0.413	389	0.755	516	-0.157	498	0.321
Al Dark	437	-0.413	428	0.744	431	-0.142	427	0.333
Lloyd Waner	438	-0.413	415	0.747	284	-0.123	269	0.353
Chris Chambliss	439	-0.414	409	0.749	432	-0.142	420	0.334
Delino DeShields	440	-0.415	464	0.729	241	-0.118	276	0.352
Dick McAuliffe	441	-0.416	421	0.746	361	-0.134	328	0.343
Marco Scutaro	442	-0.416	461	0.729	355	-0.133	360	0.341
Tommy Davis	443	-0.417	452	0.733	450	-0.145	458	0.329
Curt Flood	444	-0.417	453	0.732	332	-0.130	353	0.342
Marquis Grissom	445	-0.418	456	0.732	525	-0.159	517	0.318
Roy Smalley	446	-0.418	439	0.740	354	-0.133	319	0.345
Davey Lopes	447	-0.418	446	0.737	322	-0.129	297	0.349
Willie McGee	448	-0.418	466	0.729	405	-0.139	422	0.333
Lloyd Moseby	449	-0.419	420	0.746	454	-0.145	433	0.332
Coco Crisp	450	-0.419	462	0.729	458	-0.147	467	0.327

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
Darin Erstad	451	-0.419	432	0.743	438	-0.143	409	0.336
Ronnie Belliard	452	-0.419	395	0.753	447	-0.145	379	0.338
Yadier Molina	453	-0.421	470	0.726	445	-0.144	473	0.327
Tim Wallach	454	-0.421	458	0.732	526	-0.159	529	0.316
Willie Randolph	455	-0.422	475	0.724	119	-0.098	123	0.373
Jose Offerman	456	-0.422	455	0.732	222	-0.116	206	0.360
Brandon Phillips	457	-0.422	441	0.740	522	-0.158	503	0.320
Jason Kendall	458	-0.423	429	0.744	200	-0.113	160	0.366
Jim Fregosi	459	-0.423	448	0.736	387	-0.137	386	0.338
Juan Uribe	460	-0.423	484	0.719	558	-0.169	568	0.301
Bill Bruton	461	-0.423	483	0.720	434	-0.143	461	0.328
Luis Castillo	462	-0.424	485	0.719	136	-0.102	152	0.368
Al Bumbry	463	-0.424	482	0.721	318	-0.128	334	0.343
Doc Cramer	464	-0.424	490	0.715	335	-0.130	368	0.340
Brooks Robinson	465	-0.424	479	0.723	475	-0.149	494	0.322
Kelly Johnson	466	-0.425	404	0.751	504	-0.155	446	0.330
Mark Grudzielanek	467	-0.425	474	0.725	435	-0.143	431	0.332
Garry Maddox	468	-0.425	451	0.733	518	-0.157	504	0.320
Lonny Frey	469	-0.426	450	0.734	242	-0.118	216	0.359
Pete O'Brien	470	-0.427	426	0.745	442	-0.144	407	0.336
Don Money	471	-0.427	449	0.734	465	-0.148	463	0.328
Mark Kotsay	472	-0.427	445	0.737	451	-0.145	432	0.332
Deron Johnson	473	-0.428	459	0.731	552	-0.166	543	0.311
Willie Montanez	474	-0.429	463	0.729	469	-0.148	472	0.327
Willie Davis	475	-0.430	478	0.723	541	-0.163	544	0.311
Benito Santiago	476	-0.431	481	0.722	551	-0.166	557	0.307
Aaron Hill	477	-0.431	440	0.740	513	-0.156	489	0.323
Red Schoendienst	478	-0.433	476	0.724	396	-0.138	398	0.337
Whitey Lockman	479	-0.434	454	0.732	377	-0.136	349	0.342
Bill Doran	480	-0.434	468	0.728	278	-0.122	261	0.354
Jose Cardenal	481	-0.434	467	0.728	452	-0.145	423	0.333
Ken Oberkfell	482	-0.435	494	0.713	257	-0.120	284	0.351
Gerardo Parra	483	-0.437	472	0.725	503	-0.155	495	0.322
Charlie Hayes	484	-0.438	492	0.714	510	-0.156	528	0.316
Phil Garner	485	-0.439	496	0.711	495	-0.152	490	0.323
Jim Gilliam	486	-0.440	491	0.715	227	-0.116	205	0.360
Vic Power	487	-0.441	473	0.725	546	-0.165	533	0.315
Mark Ellis	488	-0.441	497	0.711	472	-0.148	474	0.327
Brandon Crawford	489	-0.441	489	0.715	512	-0.156	507	0.319
Jim Piersall	490	-0.441	486	0.718	460	-0.147	435	0.332
Omar Vizquel	491	-0.441	523	0.688	330	-0.130	406	0.336
Ed Kranepool	492	-0.442	517	0.693	476	-0.149	526	0.316
Tim McCarver	493	-0.442	471	0.725	453	-0.145	396	0.337
Ron Hunt	494	-0.443	488	0.715	151	-0.106	153	0.368
Al Cowens	495	-0.444	480	0.722	524	-0.158	511	0.319
Matty Alou	496	-0.445	469	0.726	375	-0.135	315	0.345
Mark McLemore	497	-0.445	520	0.690	240	-0.118	294	0.349
Peanuts Lowrey	498	-0.445	510	0.698	373	-0.135	404	0.336
Ossie Bluege	499	-0.445	502	0.707	273	-0.122	274	0.352
Adam Kennedy	500	-0.446	498	0.711	466	-0.148	465	0.327

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
Nellie Fox	501	-0.447	500	0.710	327	-0.129	300	0.348
J. J. Hardy	502	-0.448	493	0.714	560	-0.169	561	0.305
Rabbit Maranville	503	-0.448	560	0.658	424	-0.141	520	0.318
Denis Menke	504	-0.450	495	0.713	341	-0.131	338	0.343
Dave Philley	505	-0.451	499	0.710	430	-0.142	415	0.334
Tommy Harper	506	-0.452	487	0.717	427	-0.142	380	0.338
Craig Counsell	507	-0.453	525	0.686	333	-0.130	351	0.342
Phil Rizzuto	508	-0.454	505	0.706	302	-0.127	283	0.351
Orlando Cabrera	509	-0.455	503	0.707	536	-0.162	524	0.317
Dick Groat	510	-0.456	512	0.696	448	-0.145	447	0.330
Elvis Andrus	511	-0.456	515	0.695	463	-0.147	480	0.325
Terry Pendleton	512	-0.457	504	0.707	543	-0.163	530	0.316
Stan Javier	513	-0.457	501	0.708	367	-0.135	317	0.345
John Roseboro	514	-0.459	511	0.697	482	-0.149	478	0.326
Juan Pierre	515	-0.459	506	0.704	378	-0.136	332	0.343
Bob Boone	516	-0.461	556	0.661	493	-0.151	534	0.315
Willie Wilson	517	-0.463	507	0.702	492	-0.151	476	0.326
Frank White	518	-0.463	539	0.675	573	-0.177	576	0.293
Mike Bordick	519	-0.464	527	0.685	487	-0.150	493	0.323
Rajai Davis	520	-0.464	519	0.690	550	-0.166	545	0.311
Joe Orsulak	521	-0.464	509	0.698	494	-0.152	488	0.324
Mike Scioscia	522	-0.466	508	0.700	376	-0.135	321	0.344
Geoff Blum	523	-0.467	516	0.694	555	-0.168	549	0.310
Alex Gonzalez	524	-0.467	528	0.685	577	-0.183	577	0.290
Steve Sax	525	-0.468	518	0.692	416	-0.140	412	0.335
Bill Virdon	526	-0.469	513	0.696	532	-0.161	525	0.316
Chris Speier	527	-0.469	538	0.676	440	-0.144	469	0.327
Granny Hamner	528	-0.470	526	0.686	559	-0.169	564	0.303
Enos Cabell	529	-0.471	536	0.678	544	-0.163	554	0.308
Paul Blair	530	-0.472	531	0.684	563	-0.171	567	0.302
Cristian Guzman	531	-0.473	521	0.690	557	-0.169	558	0.307
Royce Clayton	532	-0.474	534	0.679	535	-0.162	541	0.312
Dave Concepcion	533	-0.474	532	0.679	486	-0.150	496	0.322
Bob Kennedy	534	-0.475	554	0.665	529	-0.160	551	0.309
Maury Wills	535	-0.475	557	0.661	400	-0.139	449	0.330
Greg Gagne	536	-0.476	530	0.684	569	-0.174	565	0.302
Tom Herr	537	-0.477	514	0.696	352	-0.132	310	0.347
Scott Fletcher	538	-0.478	542	0.674	422	-0.141	436	0.332
Frank Bolling	539	-0.479	535	0.679	540	-0.163	539	0.313
Clete Boyer	540	-0.479	548	0.670	570	-0.175	571	0.299
Otis Nixon	541	-0.480	561	0.658	323	-0.129	343	0.343
Michael Bourn	542	-0.481	524	0.687	484	-0.150	454	0.329
Jim Gantner	543	-0.481	546	0.671	514	-0.157	510	0.319
Brad Ausmus	544	-0.483	549	0.669	473	-0.149	481	0.325
Jim Davenport	545	-0.483	529	0.684	533	-0.161	516	0.318
Leo Cardenas	546	-0.483	533	0.679	549	-0.166	546	0.311
Bill Mazeroski	547	-0.484	552	0.667	567	-0.174	573	0.299
Ozzie Smith	548	-0.484	553	0.666	379	-0.136	391	0.337
Lenny Harris	549	-0.486	551	0.667	530	-0.160	518	0.318
Russ Snyder	550	-0.486	522	0.688	520	-0.158	479	0.325

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
Jim Sundberg	551	-0.486	541	0.674	480	-0.149	466	0.327
Al Lopez	552	-0.488	555	0.663	464	-0.148	475	0.326
Tommy McCraw	553	-0.490	547	0.670	564	-0.171	553	0.309
Manny Trillo	554	-0.490	558	0.660	519	-0.158	531	0.316
Del Unser	555	-0.491	537	0.677	528	-0.159	509	0.319
Garry Templeton	556	-0.492	545	0.673	566	-0.173	562	0.304
Tony Taylor	557	-0.493	543	0.673	515	-0.157	502	0.321
Tony Pena	558	-0.493	544	0.673	561	-0.170	550	0.309
Marty Marion	559	-0.494	550	0.668	499	-0.154	491	0.323
Billy Jurges	560	-0.494	559	0.660	496	-0.153	483	0.325
Luis Aparicio	561	-0.495	564	0.653	538	-0.162	542	0.311
Chico Carrasquel	562	-0.498	540	0.674	468	-0.148	424	0.333
Hughie Critz	563	-0.498	562	0.656	562	-0.170	563	0.303
Bert Campaneris	564	-0.500	565	0.653	537	-0.162	547	0.311
Derrel Thomas	565	-0.501	567	0.649	505	-0.155	523	0.317
Bill Russell	566	-0.503	568	0.648	539	-0.163	548	0.310
Jim Hegan	567	-0.503	570	0.639	572	-0.176	575	0.295
Julian Javier	568	-0.508	566	0.651	575	-0.179	574	0.296
Cookie Rojas	569	-0.509	569	0.643	554	-0.168	560	0.306
Tito Fuentes	570	-0.511	563	0.653	565	-0.172	556	0.307
Roy McMillan	571	-0.524	571	0.635	534	-0.162	535	0.314
Ozzie Guillen	572	-0.528	574	0.626	578	-0.187	578	0.287
Aurelio Rodriguez	573	-0.530	575	0.626	582	-0.200	582	0.275
Larry Bowa	574	-0.531	576	0.620	568	-0.174	570	0.300
Freddie Patek	575	-0.535	572	0.633	556	-0.168	552	0.309
Don Kessinger	576	-0.537	573	0.626	545	-0.164	537	0.314
Leo Durocher	577	-0.542	577	0.619	574	-0.177	572	0.299
Alfredo Griffin	578	-0.554	579	0.604	580	-0.191	579	0.285
Bud Harrelson	579	-0.556	578	0.616	497	-0.153	470	0.327
Tim Foli	580	-0.563	580	0.593	579	-0.190	580	0.283
Ed Brinkman	581	-0.577	582	0.580	581	-0.196	581	0.280
Mark Belanger	582	-0.585	581	0.580	576	-0.179	569	0.300

Table A.2
Ranking of Pitchers

	ERA			
	Full time & age corrected		Lifetime	
	Rank	CNST	Rank	ERA
Clayton Kershaw	1	9.615	1	2.478
Pedro Martinez	2	9.922	7	2.925
Whitey Ford	3	9.949	2	2.745
Tom Seaver	4	9.952	4	2.862
Bob Gibson	5	9.956	6	2.915
Jim Palmer	6	9.984	3	2.856
Mike Cuellar	7	10.077	15	3.138
Lefty Grove	8	10.095	11	3.058
Warren Spahn	9	10.143	12	3.086
Gaylord Perry	10	10.145	13	3.105
Juan Marichal	11	10.150	5	2.889
Roger Clemens	12	10.152	14	3.125
Don Drysdale	13	10.157	8	2.948
Phil Niekro	14	10.166	51	3.351
Carl Hubbell	15	10.167	9	2.978
Hal Newhouser	16	10.204	10	3.055
Nolan Ryan	17	10.230	22	3.193
Dazzy Vance	18	10.247	29	3.240
Catfish Hunter	19	10.270	33	3.256
Greg Maddux	20	10.274	19	3.156
Dave McNally	21	10.283	27	3.237
Randy Johnson	22	10.288	39	3.293
Dutch Leonard	23	10.292	31	3.250
Tommy John	24	10.311	48	3.342
Luis Tiant	25	10.311	42	3.304
Don Sutton	26	10.339	34	3.261
John Smoltz	27	10.354	46	3.327
Steve Carlton	28	10.357	24	3.215
Bert Blyleven	29	10.360	44	3.314
Jim Bunning	30	10.361	36	3.269
Vida Blue	31	10.373	35	3.265
Justin Verlander	32	10.376	28	3.240
Dolf Luque	33	10.377	30	3.245
Max Scherzer	34	10.382	16	3.146
Kevin Brown	35	10.391	38	3.275
Curt Davis	36	10.394	61	3.422
Bob Lemon	37	10.397	26	3.234
Bucky Walters	38	10.410	41	3.302
Curt Schilling	39	10.415	68	3.458
Jerry Koosman	40	10.418	53	3.359
Eddie Lopat	41	10.418	23	3.206
Rick Reuschel	42	10.426	54	3.373
Claude Passeau	43	10.428	45	3.319
Dwight Gooden	44	10.435	77	3.506
Billy Pierce	45	10.440	37	3.269
Lon Warneke	46	10.443	21	3.183
Adam Wainwright	47	10.447	81	3.531
Red Faber	48	10.453	18	3.149
Joe Niekro	49	10.465	92	3.593
Bob Feller	50	10.470	32	3.255

Table A.2 (continued)
Ranking of Pitchers

	ERA			
	Full time & age corrected		Lifetime	
	Rank	CNST	Rank	ERA
Robin Roberts	51	10.473	59	3.405
Dizzy Trout	52	10.473	25	3.233
Steve Rogers	53	10.475	20	3.175
Fergie Jenkins	54	10.484	47	3.338
Bret Saberhagen	55	10.504	49	3.343
Lefty Gomez	56	10.507	50	3.344
Claude Osteen	57	10.507	40	3.298
Allie Reynolds	58	10.510	43	3.304
Eppa Rixey	59	10.515	17	3.148
Charlie Root	60	10.525	90	3.586
Jerry Reuss	61	10.530	97	3.637
Milt Pappas	62	10.536	57	3.398
Orel Hershiser	63	10.538	72	3.482
Cole Hamels	64	10.539	62	3.426
Dave Stieb	65	10.556	63	3.438
Curt Simmons	66	10.557	85	3.543
Hal Schumacher	67	10.557	52	3.357
Jim Perry	68	10.559	66	3.446
Al Leiter	69	10.563	125	3.802
Zack Greinke	70	10.581	75	3.492
Burt Hooton	71	10.589	55	3.380
Camilo Pascual	72	10.591	96	3.633
Virgil Trucks	73	10.592	56	3.385
Felix Hernandez	74	10.597	60	3.419
Ken Holtzman	75	10.597	73	3.487
Larry Jackson	76	10.599	58	3.401
Bob Buhl	77	10.605	87	3.545
Tom Glavine	78	10.625	82	3.536
Jim Kaat	79	10.625	67	3.453
Lew Burdette	80	10.631	100	3.656
Paul Derringer	81	10.632	69	3.459
Tim Hudson	82	10.633	74	3.492
Bob Welch	83	10.637	71	3.467
Danny Darwin	84	10.642	129	3.837
Fernando Valenzuela	85	10.645	86	3.545
Dennis Martinez	86	10.650	107	3.697
David Cone	87	10.653	70	3.462
Mickey Lolich	88	10.662	64	3.438
Murry Dickson	89	10.679	99	3.656
Jimmy Key	90	10.691	78	3.507
Tom Candiotti	91	10.695	113	3.732
Charlie Hough	92	10.708	117	3.746
Bill Lee	93	10.722	83	3.542
Freddie Fitzsimmons	94	10.725	79	3.509
Larry French	95	10.731	65	3.444
Jon Lester	96	10.734	101	3.659
Early Wynn	97	10.741	84	3.542
Ted Lyons	98	10.745	103	3.668
Tommy Bridges	99	10.764	88	3.573
Rick Rhoden	100	10.768	93	3.595

Table A.2 (continued)
Ranking of Pitchers

	ERA			
	Full time & age corrected		Lifetime	
	Rank	CNST	Rank	ERA
Bartolo Colon	101	10.792	157	4.118
Bob Friend	102	10.794	89	3.584
Kevin Appier	103	10.799	116	3.738
Herb Pennock	104	10.802	94	3.598
Waite Hoyt	105	10.802	91	3.588
Doyle Alexander	106	10.811	119	3.757
Frank Tanana	107	10.823	102	3.662
Frank Viola	108	10.835	110	3.728
Vern Law	109	10.835	122	3.766
Rick Wise	110	10.840	106	3.687
Tom Zachary	111	10.849	111	3.728
Doug Drabek	112	10.855	114	3.735
Burleigh Grimes	113	10.874	80	3.527
Mike Mussina	114	10.876	105	3.683
Bruce Hurst	115	10.881	137	3.917
Charlie Leibrandt	116	10.882	108	3.712
CC Sabathia	117	10.884	115	3.736
Bob Forsch	118	10.884	121	3.765
Bob Knepper	119	10.897	104	3.676
Jered Weaver	120	10.904	95	3.626
Dennis Eckersley	121	10.916	76	3.501
Chris Carpenter	122	10.921	120	3.759
Mark Langston	123	10.921	142	3.967
Red Lucas	124	10.922	109	3.721
Chuck Finley	125	10.924	131	3.845
Ned Garver	126	10.927	112	3.731
Jamie Moyer	127	10.932	163	4.255
Dan Haren	128	10.949	118	3.753
Mel Harder	129	10.962	124	3.801
Red Ruffing	130	10.966	123	3.798
Jim Lonborg	131	10.973	134	3.857
Paul Splittorff	132	10.980	126	3.812
Sad Sam Jones	133	10.998	130	3.838
Mark Buehrle	134	10.999	127	3.813
Jesse Haines	135	11.016	98	3.641
Jack Billingham	136	11.025	128	3.829
Bobo Newsom	137	11.034	144	3.984
Ron Darling	138	11.039	135	3.874
Guy Bush	139	11.042	133	3.855
Jack Morris	140	11.062	136	3.900
Andy Pettitte	141	11.091	132	3.849
Danny MacFayden	142	11.097	140	3.961
David Wells	143	11.097	158	4.130
Bill Gullickson	144	11.098	139	3.930
A. J. Burnett	145	11.111	145	3.987
John Lackey	146	11.125	138	3.920
Andy Benes	147	11.131	143	3.973
George Uhle	148	11.152	146	3.993
James Shields	149	11.163	148	4.015
Steve Renko	150	11.163	147	3.995

Table A.2 (continued)
Ranking of Pitchers

	ERA			
	Full time & age corrected		Lifetime	
	Rank	CNST	Rank	ERA
Kenny Rogers	151	11.171	165	4.273
Derek Lowe	152	11.179	149	4.026
Ervin Santana	153	11.195	154	4.108
Barry Zito	154	11.196	151	4.041
Tim Belcher	155	11.197	159	4.163
Mike Torrez	156	11.199	141	3.962
Mike Hampton	157	11.216	152	4.063
Rick Sutcliffe	158	11.219	153	4.080
Aaron Harang	159	11.269	164	4.260
Kevin Millwood	160	11.273	155	4.112
Wes Ferrell	161	11.293	150	4.039
Tim Wakefield	162	11.297	174	4.413
Bronson Arroyo	163	11.302	166	4.279
Kevin Gross	164	11.309	156	4.113
Kyle Lohse	165	11.331	173	4.405
Bump Hadley	166	11.332	162	4.244
John Burkett	167	11.364	167	4.309
Mike Moore	168	11.413	171	4.389
Brad Radke	169	11.434	161	4.223
Earl Whitehill	170	11.461	169	4.358
Javier Vazquez	171	11.491	160	4.218
Kevin Tapani	172	11.584	168	4.347
Rick Porcello	173	11.600	172	4.401
Steve Trachsel	174	11.605	170	4.387
Livan Hernandez	175	11.687	175	4.436
Jeff Suppan	176	11.776	177	4.701
Bobby Witt	177	11.857	178	4.834
Esteban Loaiza	178	11.904	176	4.648

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