Physical Decline Rates: Men versus Women

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Abstract

This paper uses world records by age in running, swimming, and rowing to estimate a biological frontier of decline rates for both men and women. Decline rates are assumed to be linear in percent terms up to a certain age and then quadratic after that, where the transition age is estimated. For both men and women decline rates are smallest for rowing, followed by swimming and then running. Decline rates for women are roughly the same as those for men for the short swimming events. They are slightly larger for the longer swimming events and for the rowing events. They are largest for running, more so for the longer events than the shorter ones. The age at which there is a 50 percent decline from age 30 ranges from 64 to 88, an optimistic result for humans. The estimated decline rates can be used by non physically elite people under the assumption that their decline rates in percentage terms are similar to those of the elite athletes.

1 Introduction

An important biological question is how fast people's physical abilities decline with age. In previous work, Fair(1994, 2007) and Fair and Kaplan (2018), world records by age were used to estimate decline rates in track and field, road racing, swimming, and chess. Except for swimming, only data for men were used. More recent and better data are now available for both men and women, and Concept 2

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rowing data are available for both men and women. It is now possible to compare decline rates in men versus women, which is what this paper does.

Nearly a hundred years ago Hall (1925) pointed out the potential usefulness of athletic records to study the physiology of muscular exercise. The present paper is in this tradition. The advantage of using world records to estimate the biological frontier is that each record is based on many tries, where the best try is used. The sample in this sense is very large. This being said, some of the records are likely "soft" at the older ages because not enough elite people at these ages have participated in the event for the world record to be a good estimate of the biological minimum. More will be said about this later. Studies that have used world records are reviewed in Fair (2007). As far as I am aware there are no other studies that compare the performances of men versus women as is done in this paper.

The model used in this paper focuses on two restrictions that seem sensible biologically. The first is that after a certain age (30 is used here) the rate of decline is non decreasing with age. This is the "first derivative" restriction. The second is that the change in the rate of decline is non decreasing with age. This is the "'second derivative" restriction. In short, after decline begins, nothing gets better with age. The linear-quadratic (LQ) model used here automatically meets these restrictions. The LQ model postulates that decline rates are linear in percent terms up to a certain age and then quadratic after that, where the transition age is estimated.

It will be seen that for both men and women women decline rates are smallest for rowing, followed by swimming and then running. Decline rates for women are roughly the same as those for men for the short swimming events. They are slightly larger for the longer swimming events and for the rowing events. They are largest for running, slightly more so for the longer events than the shorter ones. The age at which there is a 50 percent decline from age 30 ranges from 64 to 88, an optimistic result for humans. The estimated decline rates can be used by non physically elite people under the assumption that their decline rates in percentage terms are similar to those of the elite athletes.

2 The Data

Data for five running events were obtained from the site of the Association of Road Racing Statisticians (AARS): *arrs.net/SARec.htm*. The data are AARS recognized world records by age. Four of the events are road racing events: 5K, 10K, Half Marathon, and Marathon, and the fifth event is 5,000 meters outdoor track. Data for both men and women were obtained. The AARS data end in 2019, and more recent data were obtained from two Wikipedia sites: $https : //en.wikipedia.org/wiki/List_of_world_records_in_masters_athletics$ and $https : //en.wikipedia.org/wiki/List_of_masters_world_records_in_road_running$. The data were obtained on October 22, 2023. For men there were 19 world records set after 2019, and for women there were 21. One of the more impressive records was age 60, women's 10K, where the record dropped from 39:10 to 36:43. This shows the softness of some of the women's records.

World records by age for swimming were obtained from the World Aquatics site: *worldaquatics.com/masters/records*. Results for six long course meters (LCM) freestyle events were obtained: 50, 100, 200, 400, 800, and 1500 meters. Data were only available in five-year intervals, 30-34, 35-39, ..., 100-104. For each interval the age was taken to be the youngest age, 30, 35, ..., 100. Data for both men and women were obtained. The data were obtained on September 2, 2023.

World records by age for Concept 2 rowing were obtained from the site: *concept2.com/indoor-rowers/racing/records/world*. The machine was RowErg; the weight was heavyweight; and the events were 100, 500, 1000, 2000, 5000, 6000, and 10000 meters. Data were also only available in five-year intervals, but in this case the age of the record holder was available. Data for both men and women were obtained. The data were obtained on September 7, 2023.

As noted above, some of the data are likely "soft" at the older ages. This is particularly true for running. To adjust for this, the oldest age for the half marathon for both men and women was taken to be 85. For the marathon the oldest age for men was taken to be 85 and the oldest age for women was taken to be 88. For swimming, the age category 100-104 was not used. For rowing, the age 95 record for men for 1000 meters rowing was excluded. Finally, the data appeared soft for the 21,097 and 42,195 meter rowing events, especially for women, and these two events were not used.

Observations with dominated times were also excluded. A time is dominated if there is a lower time at an older age. A dominated time is thus soft, which is the reason for its exclusion. There was one dominated record for rowing and three for swimming. There were a number for running, primarily because there were records at each age rather then in just five year intervals. Age 30 was used as the initial age. It may be that the percentage decline per year in the early 30's is smaller than it is after, but this possibility is not considered here. The percentage decline per year from age 30 on is assumed to be the same up to the (estimated) transition age.

Regarding possible changes over time, it may be that the estimated curves are shifting down over time as nutrition, knowledge, technology, and the like improve. For this paper it is assumed that the curves do not shift over time. The world record data are primarily since 2000. For rowing the oldest record was 2011 for women and 2010 for men. For swimming all of the records were set after 2000. For running there were only 14 records out of 313 observations used that were set before 1990, with the two earliest being in 1977.

Table 1 lists the notation for the 18 events plus one pooling case.

Table 1
The Events

Notation	Description
RU5000	Running, 5000 meters, outdoor track
RU5K	Running, 5K
RU10K	Running, 10K
RUHMA	Running, half marathon
RUMA	Running, marathon
SW50	Swimming, LCM, freestyle, 50 meters
SW100	Swimming, LCM, freestyle, 100 meters
SW200	Swimming, LCM, freestyle, 200 meters
SW400	Swimming, LCM, freestyle, 400 meters
SW800	Swimming, LCM, freestyle, 800 meters
SW1500	Swimming, LCM, freestyle, 1500 meters
RO100	Rowing, RowErg, heavyweight, 100 meters
RO500	Rowing, RowErg, heavyweight, 500 meters
RO1000	Rowing, RowErg, heavyweight, 1000 meters
RO2000	Rowing, RowErg, heavyweight, 2000 meters
RO5000	Rowing, RowErg, heavyweight, 5000 meters
RO6000	Rowing, RowErg, heavyweight, 6000 meters
RO10000	Rowing, RowErg, heavyweight, 10000 meters
ROPOOL	Rowing, RowErg, heavyweight, pooled 1000–10000 meters

In the text a “M” after the name is men, and a “‘W” after the name is women,

3 The Linear/Quadratic (LQ) Model

Let r_k denote the log of the record time for age k. Using logs means that all decline rates are in percentage terms. In the data k ranges from 30 to 101. b_k will be used to denote log of the (unobserved) biological minimum time for age k. By definition,

$$r_k = b_k + \epsilon_k \quad , \tag{1}$$

where ϵ_k is the gap between the record time and the true biological minimum time. It will be close to zero if the record time is close to the biological minimum. Otherwise it is positive.

The LQ model postulates that the decline rate (in percentage terms) is linear up to a transition age and then quadratic after that. The transition age is one of the estimated parameters. At the transition age the linear and quadratic segments are constrained to touch and to have the same first derivative. The formula for b_k is

$$b_k = \begin{cases} \beta + \alpha k, & 30 \le k \le k^*, \quad \alpha > 0 \\ \gamma + \theta k + \delta k^2, & k > k^*, \quad \delta > 0 \end{cases} \tag{2}$$

with the restrictions

$$\begin{aligned} \gamma &= \beta + \delta k^{*2} \\ \theta &= \alpha - 2\delta k^* \end{aligned} \tag{3}$$

k^* is the transition age. The two restrictions force the linear and quadratic segments to touch and to have the same first derivative at k^*. The unrestricted parameters to estimate are the intercept, β, the slope of the linear segment, α, the transition age, k^*, and the quadratic parameter, δ. The first derivative of b_k with respect to k is α up to the transition age and then increases by a constant amount (2δ) after that. The second derivative is zero up to the transition age and then constant (2δ) after that.

The equation that is estimated is then

$$r_k = \beta + \alpha k + \delta d_k (k^{*2} - 2k^* k + k^2) + \epsilon_k, \tag{4}$$

where $d_k = 0$ if $k \leq k^*$ and $d_k = 1$ if $k > k^*$. ϵ_k is greater than or equal to zero, so it has a positive mean. A positive mean poses no problem in the estimation because it is simply absorbed in the estimate of the constant term. This means that the constant β is not identified, but this is of no concern here because the derivatives do not depend on β. The equation can be estimated by non linear least squares, NLS.

The equation can also, however, be estimated under the restriction that $\epsilon_k \geq 0$ for all k. The procedure is common in the estimation of frontier production functions—see, for example, Aigner and Chu (1968) and Schmidt (1976). The added complication here is that equation (4) is nonlinear in coefficients. For linear equations the estimation problem can be set up as a quadratic programming problem and solved by standard methods.

The procedure used here is the following. In the NLS case the coefficients in equation (4) are estimated by minimizing the sum of squared residuals, $\sum_{k=1}^{K} \hat{\epsilon}_k^2$, where K is the total number of observations. Instead, one can minimize a weighted sum, $\sum_{k=1}^{K} \lambda_k \hat{\epsilon}_k^2$, where λ_k is equal to 1 if $\hat{\epsilon_k} \geq 0$ and is equal to a number greater than 1 if $\hat{\epsilon_k} < 0$. This penalizes negative errors more than non-negative ones. For the results here a value of 1000 was used for λ_k when $\hat{\epsilon}_k$ was less than zero.

It will be seen that the use of the frontier procedure instead of NLS has only a small effect on the slope coefficients and k^* and thus on the estimated derivatives. The use of the procedure primarily affects the estimate of the constant term β, which is not of concern here.

For the results below '‘age factors,” denoted R_k, are presented. They are computed as follows. Let $\hat{b}_k$ denote the predicted value of b_k using the estimated values of β, α, k^*, and δ for $k = 30, \ldots$. Then R_k is

$$R_k = e^{\hat{b}_k} / e^{\hat{b}_{30}}, \;\; k = 30, \ldots. \tag{5}$$

R_k is an estimate of the percent decline at age k from age 30. This estimate does not depend on the estimate of β, so the estimate of the constant term in the equation does not matter.

Some events have very similar coefficient estimates, and for these events pooling was done. The assumption is that the curve for each event is the same except for the intercept. The equation estimated is (n is the number of events pooled):

$$r_{ik} = \beta_1 D_{1ik} + \cdots + \beta_n D_{nik} + \alpha k + \delta d_{ik}(k^{*2} - 2k^*k + k^2) + \epsilon_{ik}, \qquad (6)$$

$$i = 1, \ldots, n; k = 30 \ldots, K_i,$$

where r_{ik} is the log of the observed record for event i and age k, D_{jik} is a dummy variable that is equal to 1 when event i is equal to event j and 0 otherwise $(j = 1 \ldots n)$, $d_{ik} = 1$ if $k \leq k^*$ and $d_{ik} = 0$ if $k \geq k^*$, ϵ_{ik} is the error for event i and age k, and K_i is the oldest age used for event i. The n β coefficients are the n different constant terms.

4 The Results

There are five running events, six swimming events, and seven rowing events, for a total of 18 cases per gender. The estimates for these 36 cases are presented in Table 2. The coefficient estimates for five rowing events, the 1000, 2000, 5000, 6000, and 10000 meter events for each gender, are close enough to warrant pooling, and the pooling estimates are presented at the bottom of Table 2.

Table 2 presents the estimates of α, k^*, δ, the implied age factors for ages 70, 80, and 90, the number of observations, the maximum age in the estimation period, the age at which the decline is 50 percent from age 30 (denoted "Half"), and the estimated standard error of the estimate of k^*. For each case the men's results are presented and then the women's. Although not shown, the coefficient estimates are highly significantly different from zero. Only one estimate of α has a t-statistic less than 2.0, 1.85 for rowing 1000 meters women, and only one estimate of δ has a t-statistic less than 2.0, 1.64 for rowing 500 meters men. This is, of course, not surprising since there is obvious decline in the data. The estimated standard errors

Table 2
NLS Estimates

Event	$\hat{\alpha}$	$\hat{k^*}$	$\hat{\delta}$	R_{70}	R_{80}	R_{90}	No. Obs.	Max Age	Half	SE $\hat{k^*}$
RU5000M	0.0096	73.3	0.00118	1.47	1.70	2.47	38	96	73	1.0
RU5000W	0.0098	63.8	0.00057	1.51	1.89	2.65	29	96	70	3.4
RU5KM	0.0077	66.0	0.00082	1.38	1.73	2.55	34	95	75	2.1
RU5KW	0.0085	63.3	0.00071	1.45	1.87	2.76	35	95	72	1.5
RU10KM	0.0089	75.4	0.00256	1.43	1.64	2.93	33	92	76	0.7
RU10KW	0.0081	64.4	0.00103	1.43	1.93	3.19	35	88	73	3.1
RUHMAM	0.0078	58.5	0.00032	1.42	1.71	2.19	35	85	74	2.3
RUHMAW	0.0090	53.9	0.00030	1.55	1.92	2.53	23	85	69	4.3
RUMAM	0.0107	73.2	0.00123	1.53	1.81	2.69	28	85	68	1.7
RUMAW	0.0122	72.9	0.00200	1.63	2.03	3.72	23	88	64	1.8
SW50M	0.0045	63.0	0.00041	1.22	1.41	1.77	14	95	84	1.5
SW50W	0.0046	68.4	0.00080	1.21	1.41	1.92	14	95	83	3.0
SW100M	0.0056	64.7	0.00047	1.27	1.48	1.89	13	95	81	2.6
SW100W	0.0048	65.1	0.00067	1.23	1.48	2.02	13	95	81	2.9
SW200M	0.0050	61.1	0.00043	1.26	1.49	1.93	14	95	81	2.2
SW200W	0.0048	62.4	0.00053	1.25	1.49	1.99	14	95	81	3.2
SW400M	0.0038	56.5	0.00037	1.24	1.48	1.90	14	95	81	1.8
SW400W	0.0043	55.2	0.00036	1.28	1.55	2.00	13	95	79	3.6
SW800M	0.0043	55.0	0.00031	1.27	1.50	1.89	14	95	80	2.6
SW800W	0.0049	56.2	0.00039	1.31	1.59	2.08	13	95	78	4.4
SW1500M	0.0052	59.2	0.00035	1.28	1.51	1.91	14	95	80	3.7
SW1500W	0.0046	55.0	0.00036	1.31	1.58	2.06	11	95	78	5.2
RO100M	0.0070	73.9	0.00057	1.32	1.45	1.76	10	91	83	4.0
RO100W	0.0059	63.5	0.00052	1.29	1.55	2.05	11	101	79	7.1
RO500M	0.0089	70.1	0.00028	1.43	1.60	1.90	10	91	75	7.6
RO500W	0.0085	62.7	0.00020	1.42	1.62	1.93	10	91	75	7.9
RO1000M	0.0051	63.2	0.00023	1.24	1.38	1.60	11	91	86	1.8
RO1000W	0.0058	57.1	0.00021	1.31	1.50	1.78	10	91	81	13.9
RO2000M	0.0046	64.4	0.00027	1.21	1.34	1.57	12	95	88	1.4
RO2000W	0.0051	62.8	0.00025	1.24	1.39	1.64	11	90	85	2.5
RI5000M	0.0045	63.7	0.00031	1.21	1.36	1.62	11	90	87	1.8
RO5000W	0.0053	66.5	0.00059	1.24	1.45	1.90	10	93	82	1.8
RO6000M	0.0040	65.5	0.00038	1.18	1.32	1.59	12	95	88	2.7
RO6000Wf	0.0047	60.9	0.00036	1.24	1.44	1.79	9	80	83	2.5
RO10000M	0.0039	62.8	0.00031	1.19	1.33	1.59	11	90	88	1.6
RO10000W	0.0048	64.5	0.00050	1.23	1.43	1.85	9	90	83	2.5
ROPOOLM	0.0044	63.5	0.00029	1.21	1.35	1.59	57	96	87	1.3
ROPOOLW	0.0050	62.3	0.00036	1.25	1.43	1.77	49	93	83	2.7

of the estimates of k^* are presented to give a sense of the precision of the estimates of the transition age. There is collinearity between the estimate of the transition age and the estimate of the quadratic coefficient. A larger estimate of k^* tends to result in a larger estimate of δ.

The one problematic result in Table 2 is for the women's marathon. The estimate of δ is fairly high, and predictions beyond about 80 are likely too pessimistic. The estimate age factor for women at age 90 is much larger than that for men, which does not seem sensible. This likely reflects the soft data problem for women in the marathon, and more time will be needed to obtain an accurate biological frontier for the women's marathon, at least at the older ages.

Not counting the women's marathon, in Table 2 the estimates of the transition age vary from 55.0 to 75.4; the estimates of α, the percent decline per year up to the transition age, vary from 0.0038 to 0.0107; and the estimates of δ vary from 0.00020 to 0.00256. The age factors at age 80 vary from 1.32 to 1.93. The age at which there is a 50 percent decline from age 30 varies from 68 for the men's marathon to 88 for some of the men's rowing events. Four of the estimated standard errors of the estimate of k^* are fairly high: 7.1 for RO100W, 7.6 for RO500M, 7.9 for RO500W, and 13.9 for RO1000W.

The results in Table 2 are summarized in Table 3, where the five rowing events, 1000 through 10000 meters, are summarized by the pooled results. The following is a discussion of this table.

Which sport has the smallest decline rates? Except for 100 and 500 meters, the rowing events have remarkably small decline rates at age 80, 35 percent for men and 43 percent for women for the pooled estimates. Next comes swimming. Running has by far the largest decline rates, roughly double compared to rowing for each gender.

Table 3
Summary: Percent Decline 30 to 80

Event	Men	Women	Difference
RU5000	70	89	19
RU5K	73	87	14
RU10K	64	93	29
RUHMA	71	92	21
RUMA	81	103	22
SW50	41	41	0
SW100	48	48	0
SW200	49	49	0
SW400	48	55	7
SW800	50	59	9
SW1500	51	58	7
RO100	45	55	10
RO500	60	62	2
ROPOOL	35	43	8

Results taken from Table 2.

How do men and women compare? Women are on par with men for the shorter swimming events. SW50, SW100, and SW200. Men have slightly less decline than women for the longer swimming events. For the longest swimming event, SW1500, the decline at age 80 is 51 percent for men and 58 percent for women, a difference of 7 percentage points.

For rowing the events RO100 and RO500 are erratic—a difference of 10 percentage points for RO100 and a difference of 2 percentage points for RO500. It could be that these two events are not estimated well. Likely more reliable are the pooled results, where the difference is 8 percentage points.

The differences for running are the largest. The difference is 19 percentage points for 5000 meters and 14 percentage points for the 5K. For the three longer distances the differences are somewhat larger at 29, 21, and 22 percentage points respectively. For running and swimming the decline rates at age 80 increase with distance more for women than for men. In other words the differences at age 80 between men and women are larger at the longer distances.

Another way of examining the differences between men and women is to plot the values by age for each. In Figure 1 the predicted values of r_k are plotted for men and women for the running half marathon. (The marathon is not used because of the problematic nature of the results for women at the older ages.) Both of these curves obviously have similar shapes—the linear/quadratic estimates—but the gap between women and men is widening with age. This is better seen in Figure 1a, where the percent decline since 30 is plotted. The gap at age 80 is 0.21 (from Table 3), and it gradually gets larger.

Figures 2 and 2a plot the same variables for swimming 200 meters. This is the event (along with swimming 50 and 100 meters) where the decline rates are essentially the same for the two genders. The only difference is that women have a larger constant term.

Figures 3 and 3a do the same for pooled rowing. (The constant term for each gender in Figure 3 is for the first pooled event, 1000 meters.) The gap widens with age, as in Figure 1a.

Overall, one would say that the differences in decline rates between men and women for swimming and rowing are zero or modest, but more pronounced for running. There is also evidence that the differences widen slightly with age for running and rowing.

How bad is aging? Overall, it seems not too bad. Table 2 shows the age at which the decline is 50 percent from age 30. These ages range from 68 for men's marathon (not counting women's marathon) to 88 for men's 2000, 6000, and 10000 meters rowing.

Figure 1

Running, Half Marathon

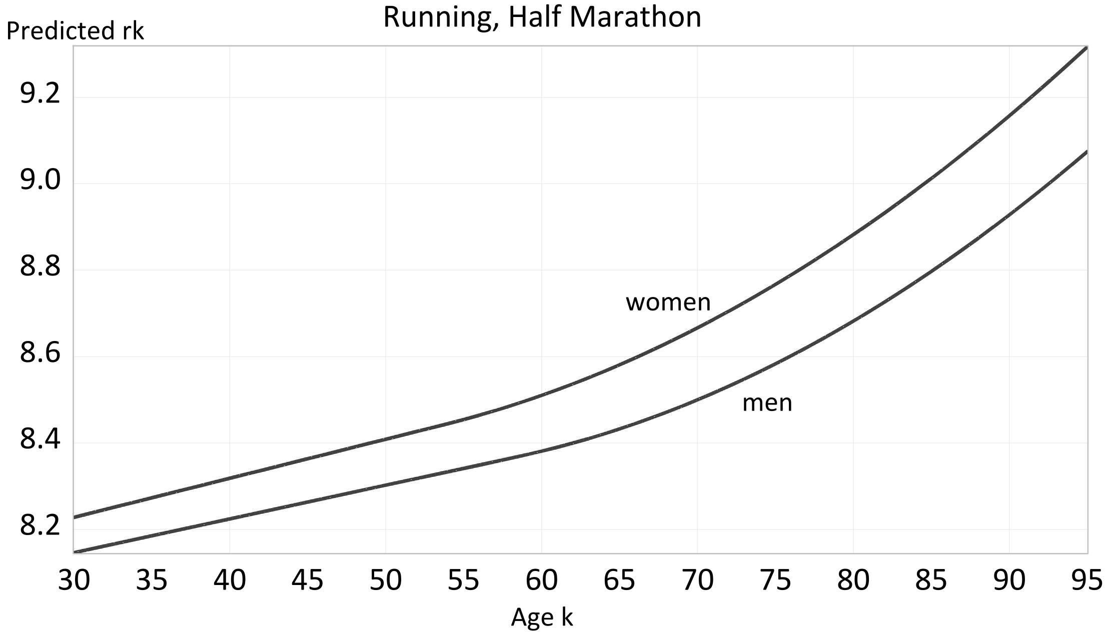


Figure 1a

Running, Half Marathon

Percent Decline Since 30

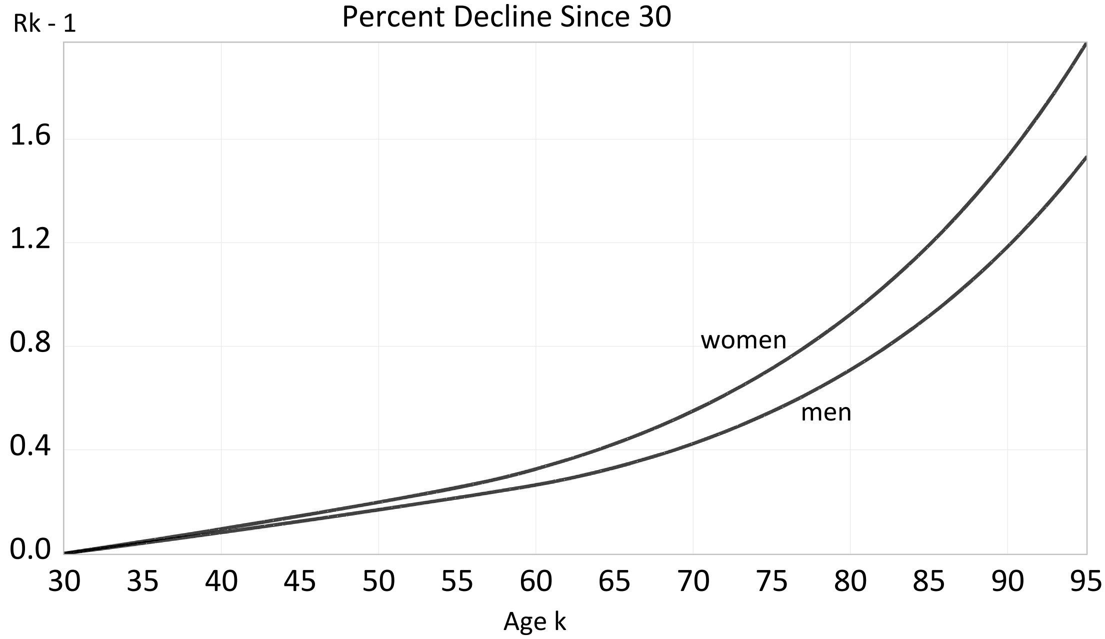


Figure 2

Swimming, 200 meters

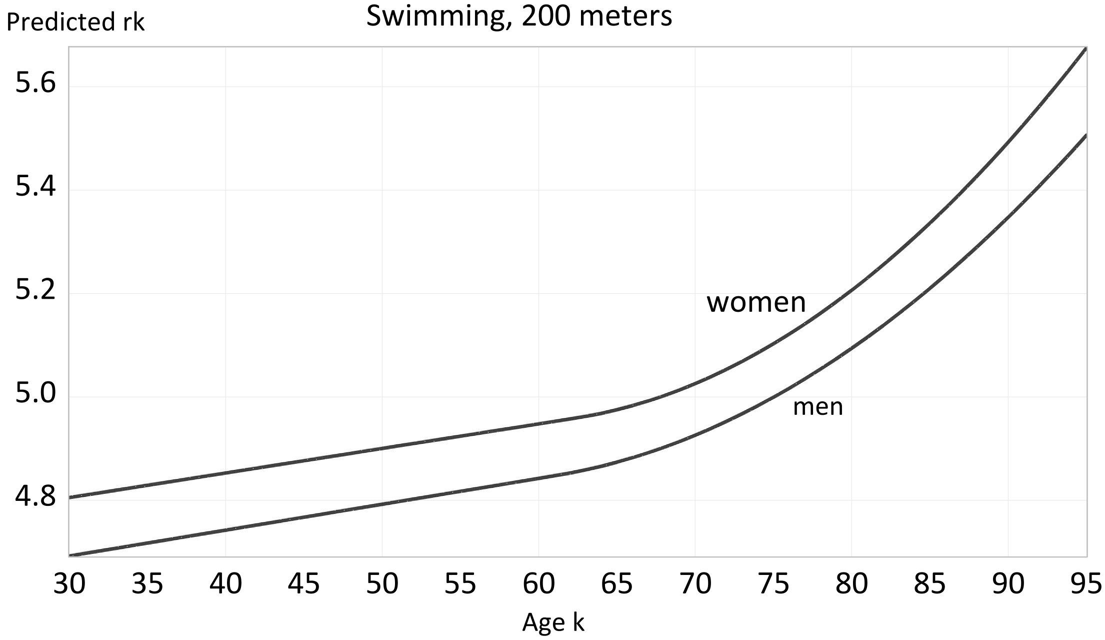


Figure 2a

Swimming, 200 meters

Percent Decline Since 30

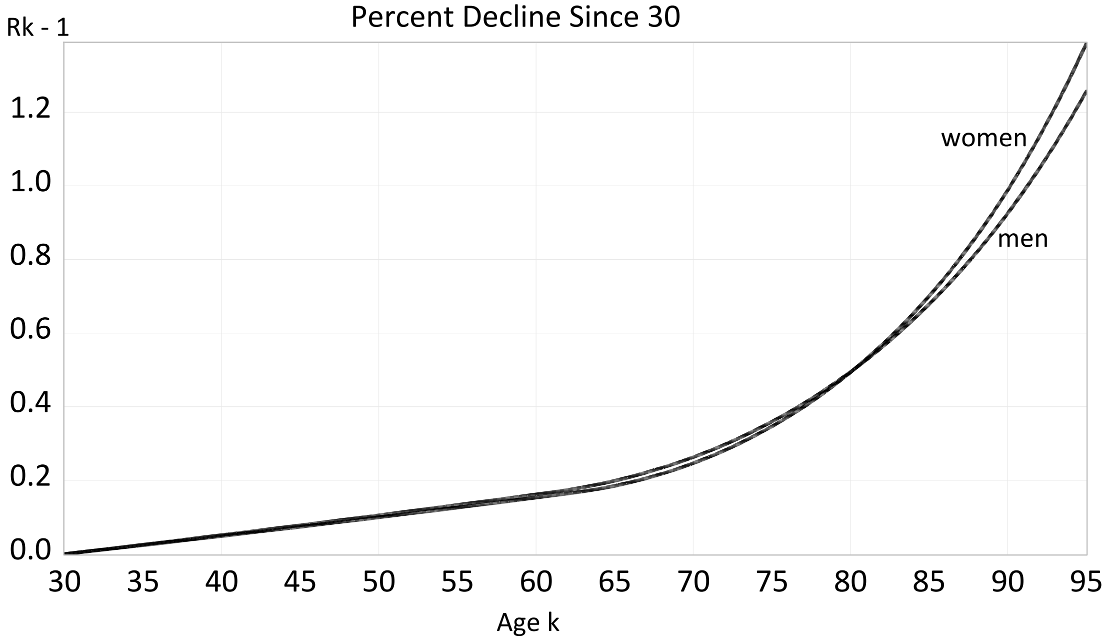


Figure 3

Rowing, Pooled 1000-10000 meters

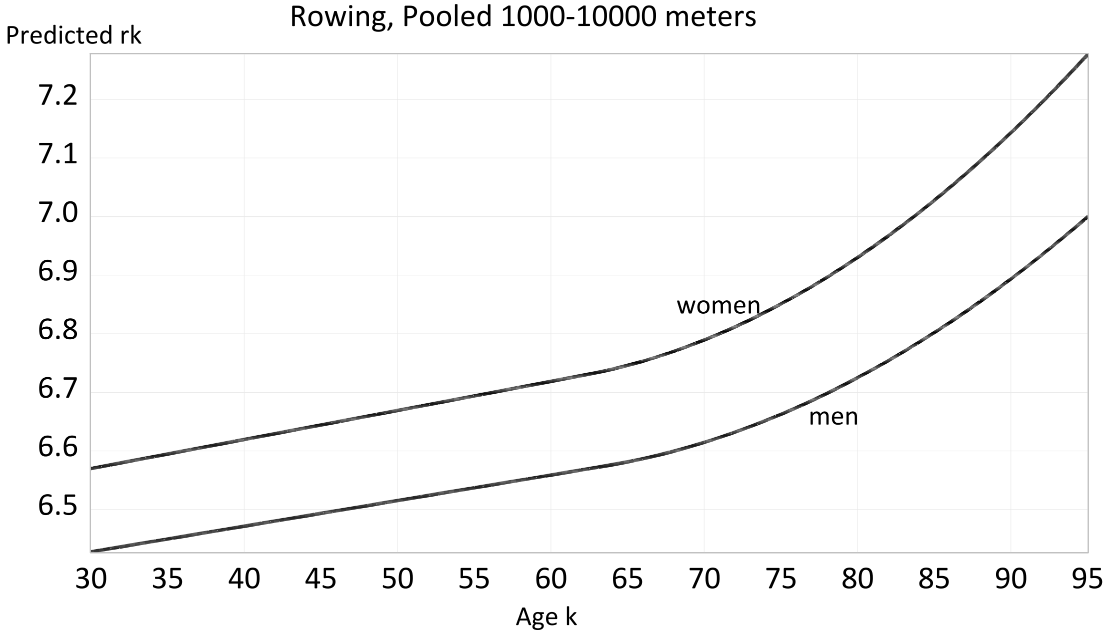
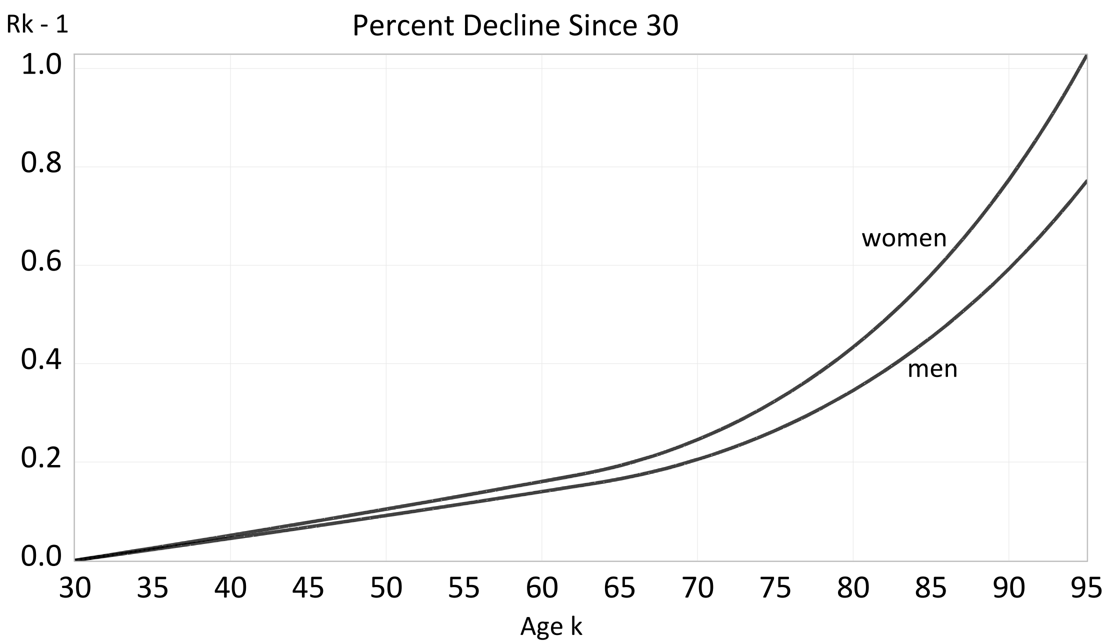


Figure 3a

Rowing, Pooled 1000-10000 meters

Percent Decline Since 30



5 Robustness

The estimates per gender for rowing for the five events 1000 meters through 10000 meters are remarkably similar in Table 2, which is why they were pooled. This is support for the specification. As noted above, the decline rates for rowing are low, which is true for all five estimates per gender.

The estimated standard errors for the estimates of the transition age are small with four exceptions as discussed above. The also adds support for the specification.

Table 4 is the same as Table 2 except that the estimates are obtained from the frontier method, where all the estimated residuals are forced to be non negative. The frontier results are quite close to the NLS results. None of the main conclusions are changed.

6 Use of the Estimated Decline Rates

A world age record is the best that anyone at that age has done, and so it is a good estimate of the biological frontier aside from the soft data problem. The decline rates are in percent terms, and they can be used by non physically elite people under the assumption that their decline rates are the same percentages as those for the elite athletes. In other words, the decline rates can be used if one is on the biological frontier regarding percentage decline rates. To be on the line also requires that one is not sick or injured and is in peak shape age corrected, a severe requirement. My experience is that some are on their line and some are not. But at least it is something to aim for.

In general, as noted above, the decline rates are modest and are encouraging for people having an active life well into the older ages. These results support the recent move in medicine to focus on active lifestyles as people age. See, for example, Attia (2023).

Table 4
Frontier Estimates

Event	$\hat{\alpha}$	$\hat{k^*}$	$\hat{\delta}$	R_{70}	R_{80}	R_{90}	No. Obs.	Max Age	Half
RU5000M	0.0094	71.9	0.00106	1.46	1.72	2.49	38	96	73
RU5000W	0.0105	70.4	0.00080	1.52	1.81	2.54	29	96	69
RU5KM	0.0083	70.0	0.00086	1.40	1.65	2.32	34	95	76
RU5KW	0.0098	68.7	0.00099	1.48	1.85	2.83	35	95	71
RU10KM	0.0086	75.1	0.00237	1.41	1.63	2.84	33	92	77
RU10KW	0.0064	55.2	0.00039	1.41	1.75	2.36	35	88	74
RUHMAM	0.0078	61.8	0.00044	1.41	1.71	2.26	35	85	74
RUHMAW	0.0084	54.5	0.00034	1.52	1.90	2.54	23	85	70
RUMAM	0.0107	74.4	0.00167	1.53	1.80	2.85	28	85	68
RUMAW	0.0112	72.7	0.00227	1.56	1.97	3.86	23	88	67
SW50M	0.0041	63.1	0.00043	1.20	1.39	1.74	14	95	84
SW50W	0.0048	69.9	0.00081	1.21	1.38	1.85	14	95	84
SW100M	0.0064	71.7	0.00074	1.29	1.45	1.88	13	95	82
SW100W	0.0061	69.0	0.00077	1.28	1.49	2.03	13	95	81
SW200M	0.0046	60.9	0.00044	1.25	1.48	1.92	14	95	81
SW200W	0.0048	65.9	0.00064	1.22	1.44	1.92	14	95	82
SW400M	0.0038	59.1	0.00042	1.23	1.46	1.88	14	95	82
SW400W	0.0050	61.8	0.00047	1.26	1.50	1.96	13	95	80
SW800M	0.0040	59.3	0.00040	1.23	1.45	1.86	14	95	82
SW800W	0.0063	67.9	0.00070	1.29	1.52	2.06	13	95	80
SW1500M	0.0049	63.7	0.00048	1.24	1.45	1.86	14	95	82
SW1500W	0.0066	66.2	0.00061	1.31	1.56	2.10	11	95	79
RO100M	0.0074	72.6	0.00049	1.34	1.49	1.80	10	91	81
RO100W	0.0095	74.6	0.00085	1.46	1.65	2.17	11	101	73
RO500M	0.0096	71.8	0.00029	1.47	1.65	1.96	10	91	73
RO500W	0.0081	64.1	0.00025	1.39	1.59	1.92	10	91	76
RO1000M	0.0050	63.2	0.00025	1.23	1.37	1.61	11	91	86
RO1000W	0.0052	58.8	0.00023	1.27	1.44	1.70	10	91	83
RO2000M	0.0048	66.2	0.00030	1.22	1.35	1.58	12	95	88
RO2000W	0.0045	58.3	0.00021	1.23	1.39	1.63	11	90	86
RI5000M	0.0046	64.2	0.00032	1.21	1.36	1.63	11	90	86
RO5000W	0.0049	66.7	0.00065	1.22	1.43	1.90	10	93	82
RO6000M	0.0046	72.3	0.00060	1.20	1.30	1.59	12	95	88
RO6000Wf	0.0040	57.2	0.00026	1.23	1.40	1.70	9	80	84
RO10000M	0.0035	61.1	0.00030	1.18	1.33	1.59	11	90	88
RO10000W	0.0044	61.9	0.00046	1.23	1.44	1.87	9	90	82
ROPOOLM	0.0044	64.0	0.00028	1.21	1.34	1.58	57	96	88
ROPOOLW	0.0045	58.1	0.00025	1.24	1.41	1.69	49	93	84

7 Conclusion

There are three main conclusions from the results in this paper, two more conclusive than the third. The first is that the decline rates are modest into the older ages. In most cases the decline is less than 1 percent per year between age 30 and the mid 60's. For rowing it is about a half a percent per year. In many cases the age at which the decline is 50 percent from age 30 is greater than 80.

The second conclusion is that decline rates are larger for running than for swimming and rowing. Although less strong, there is evidence that the decline in rowing is less than the decline in swimming.

As noted in the text, this is the first study that estimates decline rates for men versus women. The third conclusion is that except for the short swimming events there is more decline for women than for men, with the largest differences for the running events. This conclusion is, however, tentative because of the soft data problem. If the data are softer for older women than for older men, there will be in the future more records broken by women than by men, which in the estimation is likely to lower the decline rates more for women than for men. Will this be enough to eliminate the differences? It seems unlikely that the current estimates are this biased, but time will tell. One of the key events where more time is needed for both men and women is the marathon.

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