PHYSICAL DECLINE RATES: MEN VERSUS WOMEN

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October 2023

COWLES FOUNDATION DISCUSSION PAPER NO. 2371

COWLES FOUNDATION FOR RESEARCH IN ECONOMICS

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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 40 ranges from 70 to 90, 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 (40 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 40 ranges from 70 to 90, 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 18 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 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, 40-44, 45-49, ..., 100-104. For each interval the age was taken to be the youngest age, 40, 45, ..., 100. Data for both men and women were obtained. The data were obtained on September 2, 2023.

World records 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, half marathon and marathon. To adjust for this, the oldest age for these two events was taken to be 85. 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 40 was used as the initial age. There may be some decline before age 40, but this rate is likely smaller than the rate that begins at age 40. There are more observations for the running events than the others because records are available for each 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 271 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 40 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

$$b_k = \begin{cases} \beta + \alpha k, & 40 \leq k \leq k^*, \quad \alpha > 0 \\ \gamma + \theta k + \delta k^2, & k > k^*, \quad \delta > 0 \end{cases} \tag{2}$$

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 $k = 40, \ldots$. Then R_k is

$$R_k = e^{\hat{b}_k} / e^{\hat{b}_{40}}, \quad k = 40, \ldots. \tag{5}$$

R_k is an estimate of the percent decline at age k from age 40. 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):

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

$$i = 1, \ldots, n; k = 40 \ldots, K_i,$$

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 5 running events, 6 swimming events, and 7 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 5 rowing events, the 1000, 2000, 5000, 6000, and 10000 meter events, 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 40 (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. No estimate of α has a t-statistic less than 2.0, and only one estimate of δ has a t-statistic less than 2.0, 1.85 for rowing 1000 meters women. This is, of course, not surprising since there is obvious decline in the data. The estimated standard errors of the estimates of k^* are presented to

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	0.0100	73.9	0.00121	1.35	1.56	2.26	32	96	79	
RU5000W	0.0107	65.8	0.00061	1.39	1.73	2.44	26	96	75	
RU5KM	0.0084	66.9	0.00085	1.30	1.62	2.39	30	95	78	
RU5KW	0.0105	66.5	0.00078	1.38	1.76	2.61	28	95	75	
RU10KM	0.0097	76.0	0.00266	1.34	1.54	2.73	30	92	80	
RU10KW	0.0135	82.7	0.02124	1.50	1.72	6.14	29	88	71	
RUHMAM	0.0078	58.6	0.00032	1.32	1.58	2.02	29	85	78	
RUHMAW	0.0100	56.2	0.00031	1.43	1.78	2.34	20	85	73	
RUMAM	0.0107	73.3	0.00123	1.38	1.62	2.42	27	85	77	
RUMAW	0.0137	74.2	0.00221	1.51	1.86	3.44	20	85	70	
SW50M	0.0050	64.5	0.00043	1.18	1.36	1.70	12	95	85	
SW50W	0.0072	76.6	0.00145	1.24	1.36	1.86	12	95	85	
SW100M	0.0068	67.8	0.00053	1.23	1.42	1.82	12	95	83	
SW100W	0.0067	68.4	0.00075	1.23	1.45	1.99	11	95	82	
SW200M	0.0057	62.6	0.00044	1.22	1.43	1.85	12	95	83	
SW200W	0.0050	63.0	0.00054	1.19	1.43	1.90	12	95	83	
SW400M	0.0044	57.9	0.00038	1.21	1.43	1.84	12	95	83	
SW400W	0.0057	58.5	0.00038	1.25	1.50	1.94	12	95	81	
SW800M	0.0038	53.7	0.00030	1.21	1.43	1.80	12	95	83	
SW800W	0.0065	60.0	0.00042	1.27	1.53	2.02	12	95	80	
SW1500M	0.0054	59.7	0.00035	1.22	1.44	1.82	12	95	83	
SW1500W	0.0094	69.3	0.00060	1.32	1.56	2.06	10	95	79	
RO100M	0.0070	73.9	0.00057	1.23	1.35	1.64	10	91	87	
RO100W	0.0113	70.8	0.00056	1.40	1.65	2.16	10	101	75	
RO500M	0.0089	70.1	0.00028	1.30	1.47	1.74	10	91	82	
RO500W	0.0085	62.7	0.00020	1.30	1.49	1.78	10	91	81	
RO1000M	0.0052	63.7	0.00023	1.18	1.31	1.53	10	91	89	
RO1000W	0.0058	57.1	0.00021	1.23	1.41	1.68	10	91	84	
RO2000M	0.0049	65.6	0.00028	1.16	1.29	1.51	11	95	90	
RO2000W	0.0058	66.4	0.00030	1.19	1.33	1.58	10	90	88	
RI5000M	0.0051	65.4	0.00032	1.17	1.31	1.56	10	90	88	
RO5000W	0.0052	66.4	0.00059	1.18	1.38	1.81	9	93	84	
RO6000M	0.0041	65.8	0.00038	1.14	1.27	1.53	11	95	90	
RO6000Wf	0.0053	65.3	0.00052	1.19	1.39	1.80	8	80	84	
RO10000M	0.0042	63.6	0.00031	1.15	1.29	1.53	10	90	89	
RO10000W	0.0037	60.8	0.00043	1.16	1.36	1.74	8	90	85	
ROPOOLM	0.0047	64.6	0.00030	1.16	1.29	1.53	52	96	89	
ROPOOLW	0.0051	62.8	0.00037	1.19	1.37	1.69	45	93	85	

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 the transition age tends to result in a larger estimate of δ.

It will be useful to look at three problematic results in Table 2 first. One is for RO100 for women, which is the shortest rowing event. RO100W has a large estimate of α, out of line with the other estimates of α for rowing. It may thus be that the age factors in this case are not reliable—too pessimistic for women. The age factor of 1.65 for women for age 80 versus 1.35 for men seems very high.

Another is R10KW. The estimates of k^* and δ are large. (This is the collinearity mentioned above.) The estimate of k^* is 82.7, and there are only three observations above this age, 85, 86, and 88. The quadratic is thus not estimated well, which leads to an unrealistically large estimate of the age-90 age factor of 6.14. In this case the equation cannot be sensibly extrapolated to age 90. This reflects the general problem of possibly soft times for women at the older ages. The results for R10K for women in Table 2, however, seem reasonable through age 80.

A third problematic result is the marathon for women, RMAW, which has a high age-90 age factor. The maximum age for this regression is 85, and the equation appears not to predict well after this age. Many more elite women are running marathons than earlier, and this soft data problem for women is likely to be much improved in a few years.

The results in Table 2 are summarized in Table 3, where the focus is on the percent decline between 40 and 80. RO100 is excluded, and the 5 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 500 meters, the rowing events have remarkably small decline rates at age 80, 29 percent for men and 37 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

Table 3
Summary: Percent Decline 40 to 80

Event	Men	Women	Difference
RU5000	56	73	17
RU5K	62	76	14
RU10K	54	72	18
RUHMA	58	78	20
RUMA	62	86	24
SW50	36	36	0
SW100	42	45	3
SW200	43	43	0
SW400	43	50	7
SW800	43	53	10
SW1500	44	56	12
RO500	47	49	2
ROPOOL	29	37	8

Results taken from Table 2.

gender.

How do men and women compare? Women are on par with men for the shorter swimming events. SW50, SW100, and SW200, and for the shortest rowing event, RO500 (aside from RO100, which is problematic). Men have slightly less decline than women for the longer swimming events. For the longest swimming event, SW1500, the decline at age 80 is 44 percent for men and 56 percent for women, a difference of 12 percentage points. As noted above, for the rowing events except 100 and 500 meters the decline at age 80 is 29 percent for men and 37 percent for women, a difference of 8 percentage points. For running the difference is 17 percentage points for 5000 meters and 14 percentage points for the 5K. For the three longer distances the differences are 18, 20, and 24 percentage points respectively. For running and swimming the decline rates increase with distance more for women than for men.

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. 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 40 is plotted. The widening gap is clear from this figure. The other running events would be like this figure, although with slightly less of a widening gap for 5000 meters and the 5K.

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. The two figures would be essentially the same for swimming 50 and 100 meters, although for swimming 400, 800, and 1500 meters there would be a small widening gap.

Figures 3 and 3a do the same for pooled rowing. (The constant term for women in Figure 3 is for the first pooled event, 1000 meters.) Here there is a modest widening gap, as expected from Table 3.

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.

How bad is aging? Overall, it seems not too bad. Table 2 shows the age at which the decline is 50 percent from age 40. These ages range from 70 (for women's marathon) to 90 (for men's 2000 and 6000 meters rowing).

Figure 1

Running, Half Marathon

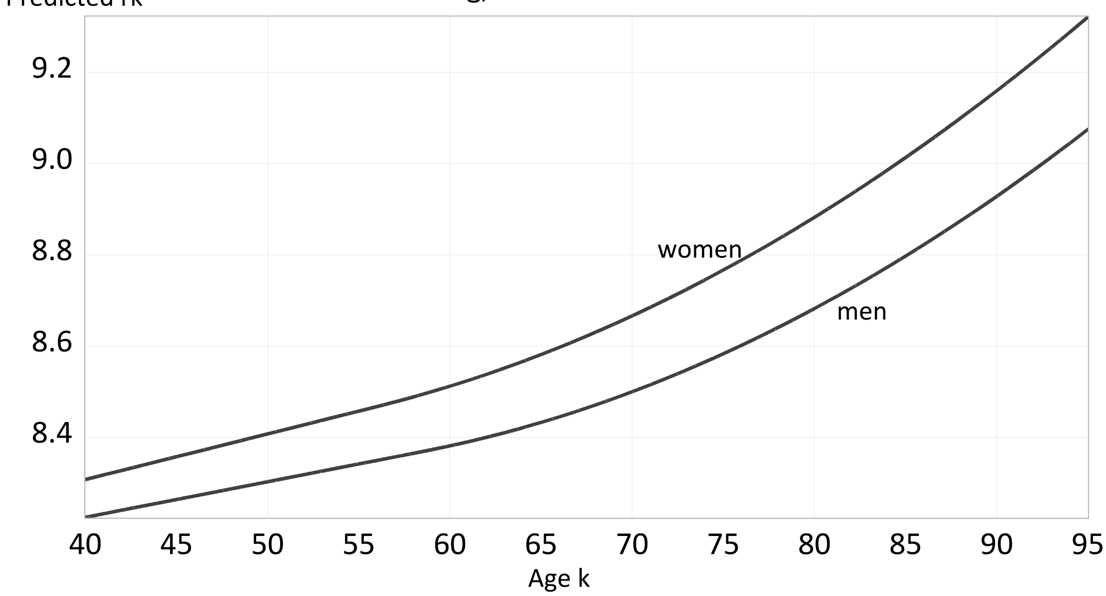


Figure 1a

Running, Half Marathon

Percent Decline Since 40

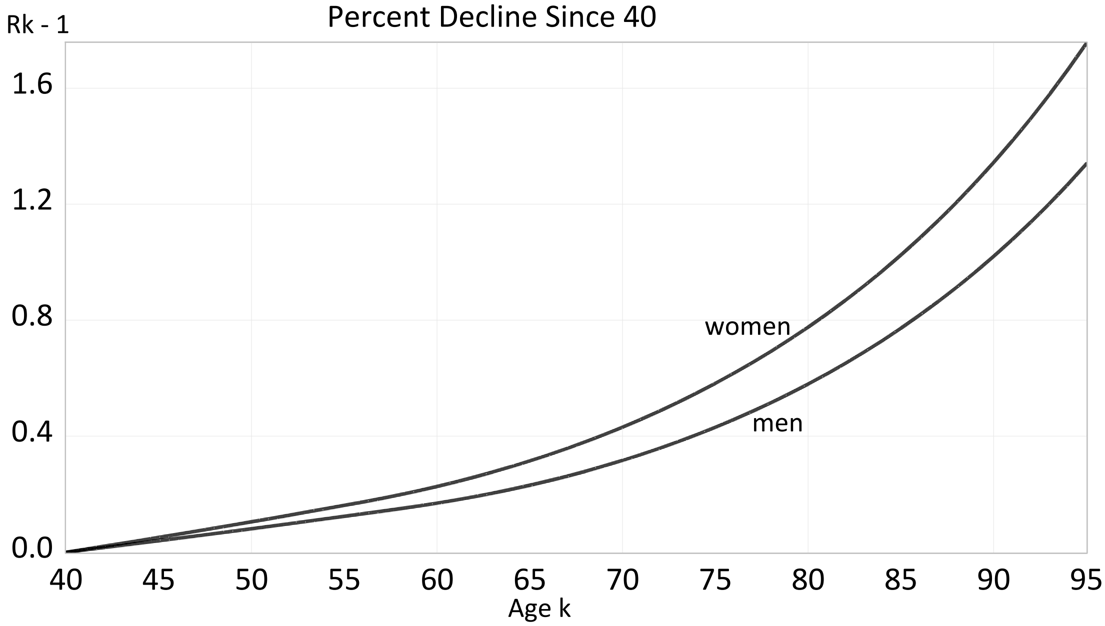


Figure 2

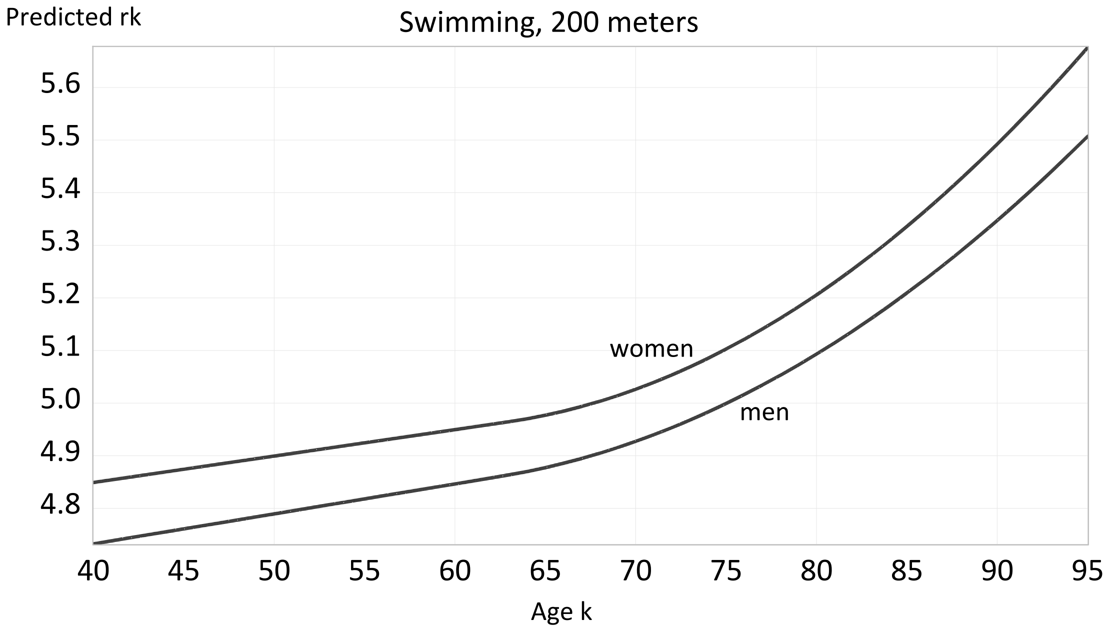


Figure 2a

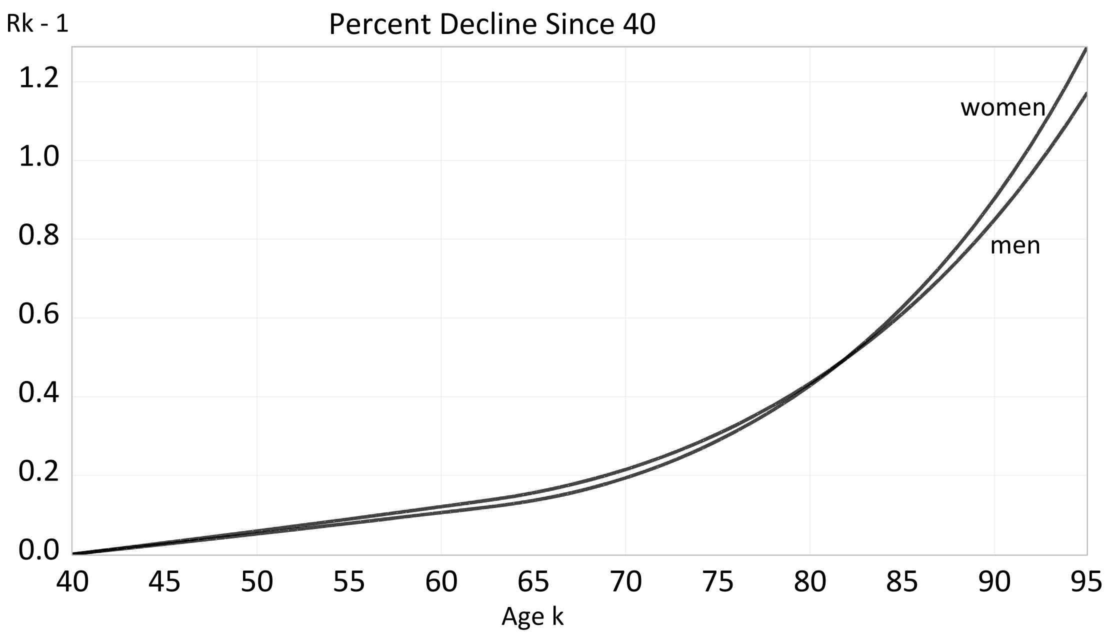


Figure 3

Rowing, Pooled 1000-10000 meters

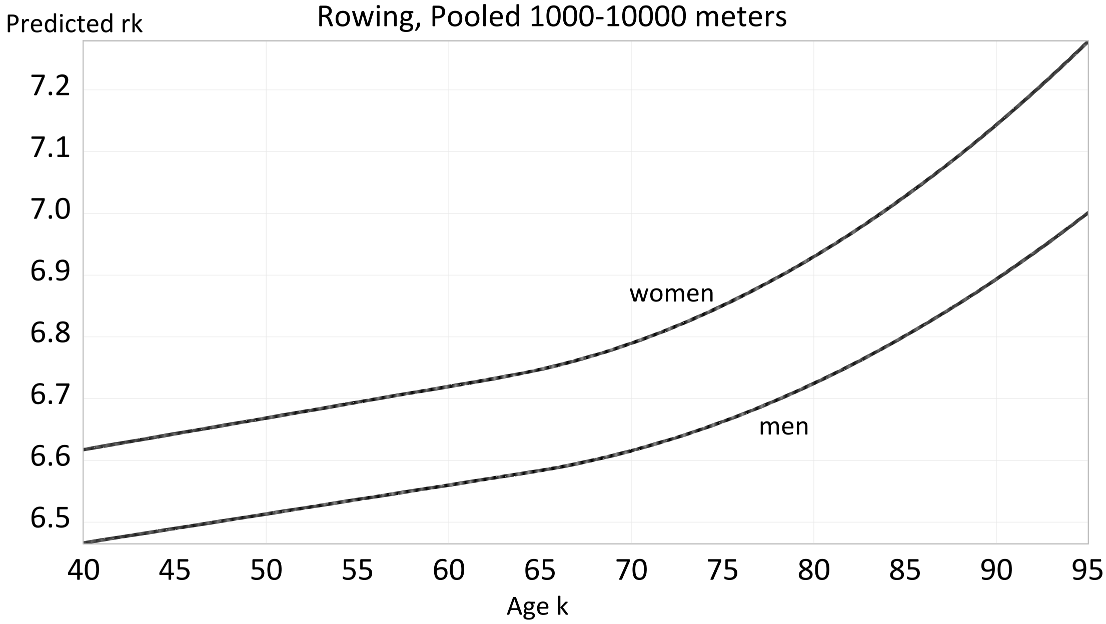
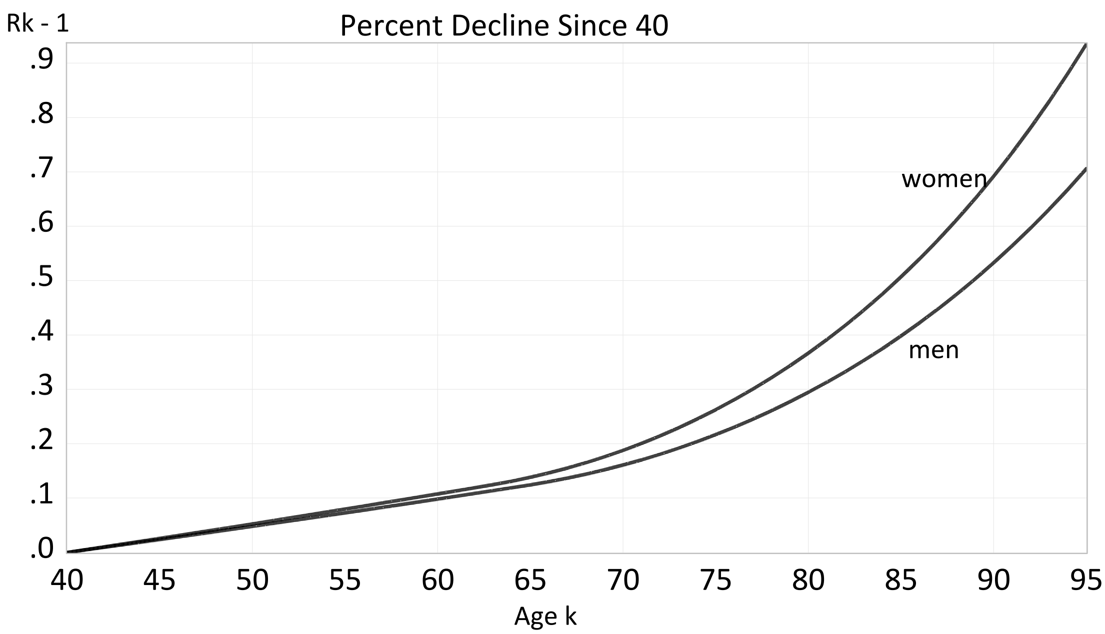


Figure 3a

Rowing, Pooled 1000-10000 meters

Percent Decline Since 40



5 Robustness

The estimates per gender for rowing for the 5 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 5 estimates per gender.

The estimated standard errors for the estimates of the transition age are small with two exceptions. One is 10.0 for rowing 100 meters for women, which is the problematic case. The other is 13.5 for rowing 1000 meters for women. This corresponds to a small transition age estimate in Table 2 of 57.1.

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.

Table 4
Frontier Estimates

Event	$\hat{\alpha}$	$\hat{k^*}$	$\hat{\delta}$	R_{70}	R_{80}	R_{90}	No. Obs.	Max Age	Half
RU5000M	0.0095	71.9	0.00106	1.33	1.57	2.27	32	96	79
RU5000W	0.0105	70.6	0.00080	1.37	1.64	2.29	26	96	77
RU5KM	0.0083	70.1	0.00086	1.28	1.52	2.14	30	95	80
RU5KW	0.0100	69.1	0.00100	1.35	1.69	2.57	28	95	76
RU10KM	0.0091	75.5	0.00244	1.31	1.51	2.64	30	92	80
RU10KW	0.0123	81.9	0.01898	1.45	1.64	6.39	29	88	73
RUHMAM	0.0078	61.8	0.00044	1.30	1.58	2.09	29	85	78
RUHMAW	0.0093	57.6	0.00037	1.40	1.75	2.36	20	85	74
RUMAM	0.0107	74.4	0.00168	1.38	1.62	2.56	27	85	77
RUMAW	0.0132	74.5	0.00262	1.49	1.84	3.64	20	85	71
SW50M	0.0051	65.6	0.00047	1.18	1.35	1.70	12	95	86
SW50W	0.0054	73.9	0.00120	1.18	1.30	1.79	12	95	86
SW100M	0.0065	72.1	0.00076	1.22	1.36	1.76	12	95	85
SW100W	0.0061	69.0	0.00077	1.20	1.40	1.91	11	95	83
SW200M	0.0057	63.5	0.00047	1.21	1.43	1.85	12	95	83
SW200W	0.0061	68.2	0.00068	1.20	1.40	1.87	12	95	83
SW400M	0.0051	61.6	0.00044	1.20	1.42	1.83	12	95	83
SW400W	0.0070	66.5	0.00056	1.24	1.47	1.93	12	95	82
SW800M	0.0039	59.0	0.00040	1.18	1.39	1.78	12	95	84
SW800W	0.0076	70.4	0.00080	1.25	1.46	1.98	12	95	82
SW1500M	0.0063	66.5	0.00051	1.21	1.41	1.81	12	95	83
SW1500W	0.0094	71.7	0.00078	1.33	1.54	2.08	10	95	79
RO100M	0.0074	72.6	0.00049	1.25	1.38	1.68	10	91	85
RO100W	0.0121	80.5	0.00113	1.44	1.62	2.02	10	101	74
RO500M	0.0096	71.8	0.00029	1.33	1.50	1.78	10	91	81
RO500W	0.0081	64.1	0.00025	1.29	1.47	1.77	10	91	82
RO1000M	0.0053	65.1	0.00027	1.18	1.31	1.54	10	91	89
RO1000W	0.0052	58.8	0.00023	1.20	1.36	1.62	10	91	86
RO2000M	0.0051	67.5	0.00031	1.17	1.29	1.51	11	95	90
RO2000W	0.0064	67.8	0.00030	1.21	1.35	1.60	10	90	87
RI5000M	0.0048	65.1	0.00033	1.16	1.30	1.56	10	90	89
RO5000W	0.0054	67.7	0.00067	1.18	1.37	1.82	9	93	84
RO6000M	0.0046	72.3	0.00060	1.15	1.25	1.52	11	95	90
RO6000Wf	0.0030	54.0	0.00024	1.16	1.33	1.58	8	80	88
RO10000M	0.0036	61.4	0.00031	1.14	1.28	1.54	10	90	89
RO10000W	0.0036	60.3	0.00044	1.16	1.37	1.76	8	90	85
ROPOOLM	0.0047	64.7	0.00029	1.16	1.29	1.52	52	96	90
ROPOOLW	0.0057	64.5	0.00031	1.20	1.35	1.62	45	93	87

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).

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 40 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 40 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.

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