DOCUMENT RESUME

ED 382 648 TM 023 082

AUTHOR Wainer, Howard; De Veaux, Richard D.
TITLE Resizing Triathlons for Fairness.
INSTITUTION Educational Testing Service, Princeton, N.J.
REPORT NO ETS-RR-94-15
PUB DATE Apr 94
NOTE 16p.
PUB TYPE Reports - Evaluative/Feasibility (142)

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS *Aquatic Sports; *Athletes; *Bicycling; Participation; *Running
IDENTIFIERS *Fairness; *Triathlons

ABSTRACT

As currently configured, triathlons are dominated by cyclists and runners. The concept of fairness, as applied to triathlons, suggests that a cyclist, runner, and swimmer, all equally proficient, can each traverse the associated segment of the triathlon in approximately equal times. This definition of fairness is used to derive fair triathlon proportions for various total elapsed times. The equal variance argument is explored, and a plan is proposed for the Ultimate Paris-to-London Triathlon. World records for the three sports are used to produce estimated distances traversed. These alternative proportions make the three segments more equal and should encourage the participation of swimmers. While the Paris-to-London route is a bit longer than the analysis suggests, it is more appealing than the ideal that would start a little east of Paris and end a little north of London. An appendix considers statistical bias in the analysis, and one figure illustrates the discussion. (Contains 5 references.) (SLD)

RR-94-15

RESEARCH REPORT

RESIZING TRIATHLONS FOR FAIRNESS

Howard Wainer
Richard D. De Veaux

Educational Testing Service
Princeton, New Jersey
April 1994

This article will be appearing in *Chance, 7 (1)*, 1994. All references should be to that source.

Resizing Triathlons for Fairness

Howard Wainer — Education Testing Service
Richard D. De Veaux — Princeton University

1 Introduction

In the country of Brogdinnian, a free college education is offered to the top scorers on a test of general academic ability. The test is made up of two parts: a verbal part and a mathematical part. Women do better on the verbal part, men better on the mathematical. There are 100 questions worth one point each on the test; 80 are mathematical questions and 20 are verbal. Almost all of the scholarships go to men. In a recent class action suit women claimed that the contest was unfair. The defense attorney countered that since the variance of math tests is smaller than that of verbal tests, more math questions are needed to spread out the competition. The judge, however, saw through this argument, pointing out that while variance is indeed important, the test proportions must take into account the mean performance for each group, and ruled in favor of the women.

While most people would agree that such an academic competition is unfair, the most common triathlon races contain proportions that are grossly unfair to a large potential pool of participants. The typical triathlon is composed of three parts: swimming, bicycling, and running. The winner is determined by the total amount of time needed to complete all three parts. It is clear that to be fair to athletes with special expertise in each of the three components the distances for each event should be chosen carefully. A race of 100 yards cycling, 25 yards swimming and 25 miles of running would be considered unfair to everyone except experienced marathon runners. Certainly no one anticipating competing in such a triathlon would waste much time training for anything but for the run.

The triathlon distances described here illustrate our point in the extreme. While existing distances for triathlon proportions are less extreme than these, they are still a long way from being fair to all athletes who might consider participating. Of course, to make progress toward a fair triathlon, we must define what we mean by fair. The ideal set of distances should be symmetric in some sense, but how to measure the symmetry is unclear. We would like a relatively strong or weak performance in any one segment to be equally rewarded or penalized. If we use total time to determine the winner, we need to make the variances of the times of each segment equal. This argument has been used to justify the relatively long cycling segments of the current Iron Man and Olympic Triathlons. We maintain that the argument is specious in this context, and fails to take into account the variance that would obtain if a different group of athletes, specifically those less predisposed toward cycling, were to participate.

Instead, we will take "fairness" to mean that a cyclist, runner and swimmer, all equally proficient, can each traverse the associated segment of the triathlon in approximately equal times. That is, the best swimmer in the world can complete the swimming segment in about the same amount of time as the best runner in the world can complete the running segment and the best cyclist the cycling segment.

In this article we use this definition to derive fair triathlon proportions for various total elapsed times. We discuss the equal variance argument further in the discussion section. We conclude with a plan for the Ultimate Paris-to-London Triathlon.

2 How long is a triathlon?

What are the proportions of a triathlon? Triathlons come in all sizes and shapes; a sampling of them is shown in Table 1. Here we show two well known triathlons, the Iron Man and the Standard International, or Olympic Triathlon, along with the Garden State Tin Man.

Table 1
Some typical triathlons

Race	Swimming	Running	Cycling	Total
Iron Man				
Distance (kilometers)	3.9	42.1	180.2	226.2
Proportions	1.7%	19%	80%	100%
International (Olympic) Triathlon				
Distance (kilometers)	1.5	10	40	51.5
Proportions	2.9%	19%	78%	100%
Garden State Tin Man Triathlon				
Distance (kilometers)	0.8	10	37	47.8
Proportions	1.6%	21%	77%	100%

How were the proportions selected? Legend has it that the first triathlon came about as the result of a bar bet by some sailors stationed in Hawaii. Previously some of them had participated in the annual events known as the Waikiki Rough Water Swim, the Around the Island Bicycle Race and the Honolulu Marathon. One proposed the challenge to complete the equivalent of all three events in one day. Thus the Iron Man Triathlon was born. It has now been contested every October since 1981 in the village of Kailua-Kona on the island of Hawaii. It consists of a 2.4 mile swim, a 26.2 mile run, and a 112 mile bicycle ride, precisely the distances of the pre-existing events. (The record for this race of 8:09:15 was set by Mark Allen in 1989.) The order of the three events, for logistical and physiological reasons, is swimming, cycling and running. While it would be interesting to consider the effects of other orderings, we will assume the standard order throughout this article, thus also ignoring the changing effect fatigue would play in a different sequence.

Note that the ratio of the distances is 1:11:48, the length of the run is 11 times the length of the swim and the length of the cycling course is 48 times the length of the swim. While the organizers of triathlons are free to choose any distances they want, many are roughly scaled versions of the Iron Man, with a few exceptions. Are these proportions fair to all potential participants? To judge this let us hold the running segment of the contest constant and calculate "fair" lengths of the other two segments.

The great Ethiopian runner Belayneh Densimo ran the Rotterdam marathon in 1988 in just under two hours and seven minutes (2:06:50), the fastest marathon ever. Marathon courses vary considerably, but there is reasonable consistency among marathon times, and 2:07 seems to be a plausible figure to represent pretty much the best possible so far.

How far can the best bicyclists go in two hours and seven minutes? This year Spain's Miguel Indurain won the 21 stage, 2,490 mile Tour de France in just under 101 hours, thus averaging almost 25 mph. This provides us with a lower bound of 53 miles for two hours and 7 minutes. Courses differ, and surely cyclists would be able to go harder if the race was to be only two hours. As we shall derive later, a good estimate for what would be a world record cycling distance for 2:07 is about 60 miles. Thus, we see that a fair Iron Man would shrink the cycling leg almost in half.

What about swimmers? How far can the best swimmers go in two hours and seven minutes? This is a little hard to estimate since the longest pool race is 1,500 meters and the world record for that, held by Australia's Kiren Perkins, is 14:43.48. This record means that for 15 minutes he can maintain a pace of just under 59 seconds per 100 meters. There are open water marathon races that take many hours, but currents, low water temperatures and other nonstandard conditions make them a poor source of data for estimating optimal human performance. Another count against using open water races is that marathon swimming is not a particularly popular sport and hence most of the greatest swimmers do not participate. Instead we have opted to use a less formal source to estimate swimming ability: performance in practice. Records kept by Rob Orr, coach of the Princeton men's swimming team revealed that sometimes in a two hour practice they can complete 10,000 meters. Kiren Perkins, whose practices are legendary, has maintained a 1:02 pace per 100 meters for two hours. Using this pace as a standard would yield a total of approximately 12,300 meters in two hours and seven minutes. Making a more conservative estimate (1:03.5) still yields 12,000 meters (about 7.5 miles). Thus, a fair Iron Man would need to more than triple the swimming leg while simultaneously halving the cycling portion.

Most triathlons are open water swims, rather than pool swims, and therefore our estimate of 12,000 meters is quite possibly a bit optimistic (depending on the direction of the current!). However, since running is the last event, the estimate of 26.2 miles for 2:07 will also be optimistic in the context of a triathlon. We use 12,000 meters as a starting point for a discussion of a fair triathlon, with a view toward re-evaluating the proportions using actual split times for participants once they become available.

Consequently, a triathlon like the Iron Man, in which each leg was scaled to be a shade over two hours long for the best in the world (competing in peak circumstances and without the distraction of the other two events), would not be proportioned 1 to 11 to 48 as is currently the case, but rather 1 to 3.5 to 8. The current Iron Man has a cycling leg that is six times longer than it ought to be relative to swimming! It is no wonder that very few triathletes describe themselves as primarily swimmers. The contest is so tilted against them that it is hardly worth a swimmer's effort to compete.

So far we have focused primarily on a single race, the Iron Man, and derived fair proportions for it. As we indicated in Table 1, not all triathlons are the same length, nor do they have the same proportions as the Iron Man. For example, the Triathlon World Championship race, which is held annually, consists of a 1.5 kilometer swim, a 40 kilometer bike ride and a 10 kilometer run. (The record of 1:48.20 was set by Miles Stewart of Australia in 1991.) These distances have become the standard distances for international competitions, and will be used in the Olympics. The ratio of these distances is roughly 1:7:27. Although this is fairer to swimmers than the Iron Man, it is still not fair, the running section being twice as long as it should relative to the swim, and the cycling leg over three times as long.

3 Data and analyses

Table 2 shows the world records for the three sports at various distances. (The cycling data are from Van Dorn 1991; running and swimming data from Meserole 1993.) We have included an imputed world record for 12,000 meters swimming based on practice performance.

Table 2
World Records in three sports

Cycling Records		Running Records		Swimming Records	
Distance(m)	Time (h:m:s)	Distance(m)	Time (h:m:s)	Distance(m)	Time (h:m:s)
1,000	0:01:05	800	0:01:42	50	0:00:21.8
4,000	0:04:30	1,000	0:02:12	100	0:00:48.4
5,000	0:05:51	2,000	0:04:51	200	0:01:46.7
10,000	0:11:53	3,000	0:07:29	400	0:03:45.0
20,000	0:24:06	10,000	0:27:08	800	0:07:47.9
40,200	0:49:24	20,000	0:56:57	1,500	0:14:43.5
80,450	1:43:46	25,000	1:13:56	*12,000*	*2:07:00.0*
100,000	2:14:02	30,000	1:29:19		
160,900	3:45:17	42,195	2:06:50		

Fitting a mathematical function to these record times allows us to interpolate accurately between them and to produce estimated distances traversed for all three sports for any intermediate time. Regression, fitting the logarithm of distance (in meters) to polynomials in the logarithm of time (in seconds) is used to estimate the relationships. The functions that were fit are shown in Figure 1.

Table 3 provides guidelines for what might properly be called "Equilateral Triathlons" of various duration, based on world record times for each segment. The distance proportions for equilateral triathlons are roughly 1 to 3.5 to 8 (depending on the duration of the segments), or 8% to 28% to 64%. The range extends from a "sprint" triathlon, that most competitors should be able to complete in under an hour, to an Equilateral Iron Man that might take a professional triathlete 8 to 10 hours to finish. For example, the entry for the equilateral equivalent of the Olympic Triathlon (keeping the running leg constant) is found on the third line of the table and consists of a 2.7km swim, a 10km run and a 22.4km cycling leg. Compare these to the current Olympic distances of 1.5km swim, 10km run, and 40km cycle.

Table 3

Equilateral Triathlons

World Record Times for each leg (minutes)		Distances (kilometers) Swim	Run	Bike	Distances (miles) Swim	Run	Bike
	10	1.0	3.9	8.5	0.6	2.4	5.3
	15	1.5	5.7	12.5	0.9	3.5	7.8
"Olympic"	28	2.7	10.0	22.4	1.7	6.2	13.9
	30	2.9	10.8	24.2	1.8	6.7	15.0
	45	4.3	15.8	35.7	2.7	9.8	22.2
	60	5.7	20.7	47.0	3.6	12.8	29.2
	75	7.1	25.5	58.1	4.4	15.9	36.1
	90	8.6	30.4	69.2	5.3	18.9	43.0
	105	10.0	35.2	80.2	6.2	21.9	49.8
	120	11.4	40.0	91.1	7.1	24.8	56.6
"Iron Man"	127	12.0	42.2	96.2	7.5	26.2	59.7

4 Discussion

In this account we tried to expose the unfairness of triathlons as currently configured. We offered alternative proportions that make the three segments of the triathlon, in some real sense, equal. By instituting these proportions we feel that there will be greater participation from athletes whose best sport is swimming, rather than the current domination by cyclists and runners. Our recommendations have not met with universal approbation. Some feel that our definition of fairness is incorrect. One common complaint was first offered by Sean Ramsay, a well known Canadian triathlete, who suggested that the current distances were chosen to equally spread out the competitors. Hence the amount of discrimination among competitors that can be achieved in a relatively short swimming race required a much longer cycling race. Ramsay's observation is true for the athletes that currently compete in triathlons. Would it be true if the races were proportioned differently?

Let's imagine a different pool of competitors for the equilateral triathlons. Perhaps more swimmers will compete. Then, the variation of cycling times will become much larger because in addition to the current variation we see in cycling times, there is the additional variation due to the participants for whom cycling is not their best sport. Therefore, the decrease in variation due to the relatively shorter cycling leg of an equilateral triathlon may be compensated for by the increased variation expected for the new pool of participants. To determine the extent to which this is true requires gathering data from equilateral triathlons. It is likely that these data would include some athletes who currently don't participate. We expect the pool of participants to change as the triathlons become fairer. The analysis of such data will then allow the iterative refinement of the triathlon proportions based on actual splits.

To conclude our exposition, we extrapolate our definition of a fair triathlon a little further (further perhaps than ought to be done). We would like to propose a new race:

5 The Ultimate Paris - to - London Triathlon.

Imagine the race beginning at dawn on a sunny day in mid-August from beneath the Arc de Triomphe in Paris. The crowds cheer as cyclists set out for Calais, 250 kilometers away. The best of them begin to arrive in Calais at about noon. They strip away their cycling clothes and grease their bodies for the 46 kilometer swim across the English Channel to Dover. Although the weather is perfect and they have caught the tide, few will come close to Richard Davey's 1988 record of 8 hours and 5 minutes. The leaders start emerging 9 to 10 hours later. The sun has already set. These hardy souls grab a quick bite to eat, change into running shoes and set off on shaky legs for London, a mere 115 kilometers away. A good ultramarathoner, starting fresh, would cross the finish line in Trafalgar Square after about 6 hours; indeed a world class race walker could do it in about 7 1/2 hours. But no one is fresh, and no one who has emerged from the Channel is a running specialist. In fact, the only ones who have finished the swimming segment so far are chubby channel swimmers. The waiting crowd looks anxiously through the darkness for the sleek cyclists and runners who traditionally win triathlons. As the sun begins to rise none emerge. At the finish line the winner arrives, half jogging, half walking more than 24 hours after the beginning of the race. She gracefully accepts the trophy and prize money and then heads for a bath, breakfast, and a bed.

The careful reader will notice that the Paris to London swimming segment is a bit longer than our equilateral analysis suggests. (It also places the swimming segment second for logistical reasons.) This could be corrected by beginning the race a bit east of Paris and finishing the run somewhat north of London. But the disparity here is small in comparison to the disadvantage to which swimmers are ordinarily put. In addition, the appellation "The Ultimate La Queue en Brie to Chigwell Triathlon" has neither the cachet nor the euphony of our proposal.

Acknowledgements

The first author's time for this research was partially supported by the ETS Senior Scientist Award. He would like to express his gratitude for this to the Trustees of the Educational Testing Service. In addition, we are grateful for advice from Harald Johnson, Jeffrey Justis, Robert Mislevy, John Rolph, Linda Steinberg, Hal Stern and Rebecca Zwick on an earlier draft. Any remaining errors are the authors'.

References

[1] Keller, J. B. (1977). A Theory of Competitive Running in *Optimal Strategies in Sports*. S.P.Ladany and R.E. Machol (eds.). pages 172-178. North Holland: The Hague.

[2] Meserole, M. (ed.) (1993). *The 1993 Information Please Sports Almanac*. Boston: Houghton Mifflin.

[3] Smith, R.L.(1988). Forecasting records by maximum likelihood. *Journal of the American Statistical Association*. vol. 83, 331-338.

[4] Tryfos, P.& Blackmore, R. (1985). Forecasting records. *Journal of the American Statistical Association*. vol. 80, 46-50.

[5] Van Dorn, W. G. (1991). Equations for predicting record human performance in cycling, running and swimming. *Cycling Science*, September & December 1991, 13-16.

Appendix

The notion of a bias in inferences drawn from the results of existing triathlons due to the self-selection of athletes into the event is subtle, although the size of the bias may be profound. Even Harald Johnson, the publisher of *Swim Bike Run* magazine and a perceptive observer of triathlons, missed it. In an 1982 open letter that he wrote to his subscribers, he discussed the difficulties in balancing triathlons. He analyzed the split results of three 1981 triathlons and arrived at proportions of 1:4:11. These are closer to our recommendations than current practice but still not quite right. The difference is accounted for because he used split times from existing triathlons. Indeed he said that "analysis of actual triathlons is the only way to do this kind of research." But of course the split times would be quite different if the proportions were different. The subtle nature of the effect of self-selection is best exposed if we express the problem mathematically.

Let S_i equal the time for person i to complete the swimming leg, R_i equal the time for person i to complete the running leg, and C_i equal the time for person i to complete the cycling leg. Moreover, let K_i be an indicator variable that takes the value 1 if person i decides to participate in the triathlon, and 0 if not. So far we have chosen distances so that World Record(S)= World Record(R)=World Record(C) over all individuals i. Ramsay's criticism was that the distances should be chosen so that

$$\mathrm{Var(S)} = \mathrm{Var(R)} = \mathrm{Var(C)}. \tag{1}$$

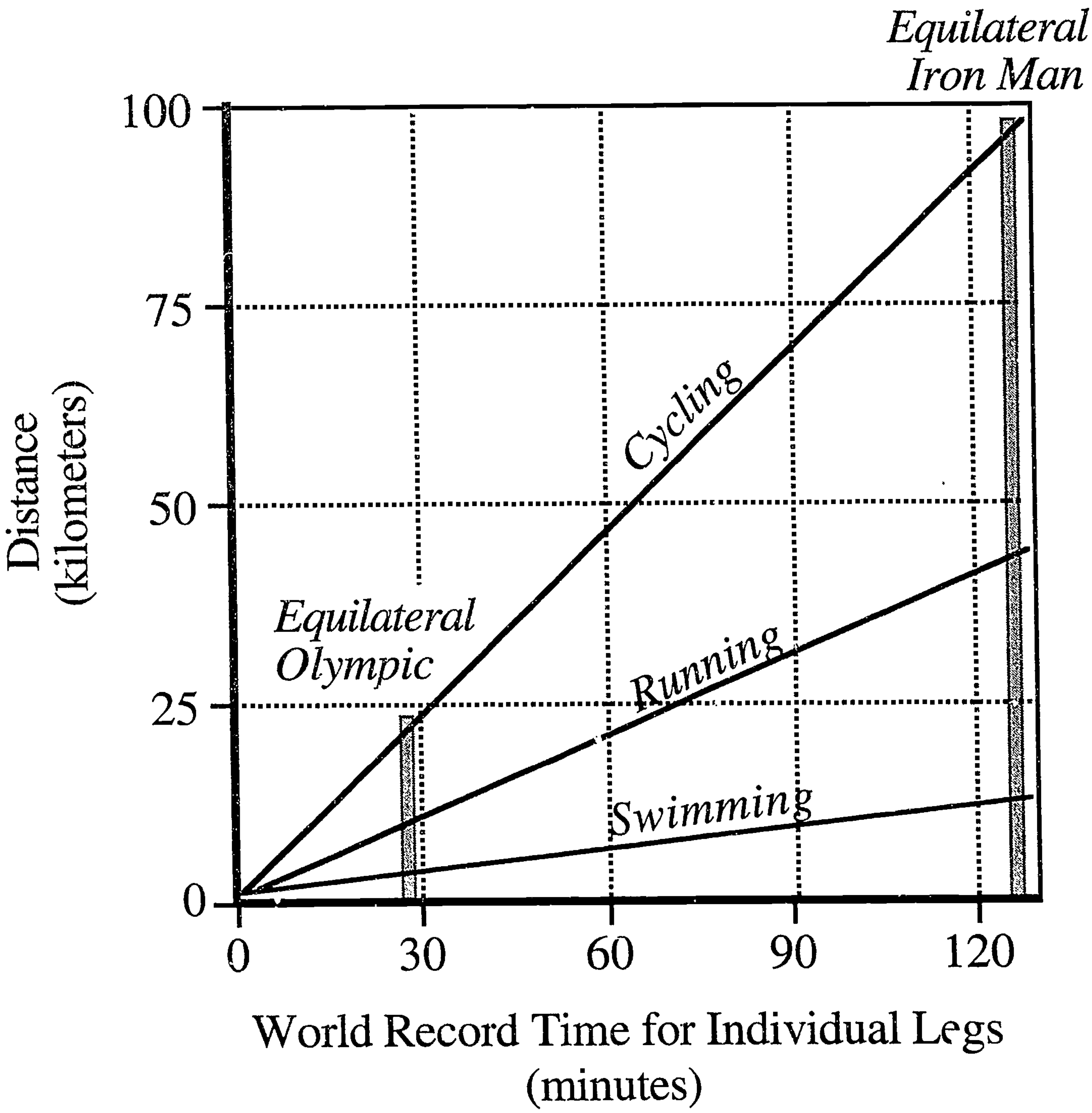
Perhaps, but all we can observe is that

$$\mathrm{Var}(S_i|K_i = 1) = \mathrm{Var}(R_i|K_i = 1) = \mathrm{Var}(C_i|K_i = 1). \tag{2}$$

However $\mathrm{Var}(S_i)$ is composed of two sets of terms. One set is observable: $\mathrm{Var}(S_i|K_i = 1)$ and $\mathrm{E}(S_i|K_i = 1)$. But the second component is unobservable because it contains both the mean and the variance of performance for those potential triathletes who did not participate: $\mathrm{Var}(S_i|K_i = 0)$ and $\mathrm{E}(S_i|K_i = 0)$. Moreover, since the pool of potential participants is defined only loosely, we also cannot observe $\mathrm{P}(K_i = 1)$. All of these quantities are unobserved and unknown. There is a similar term for each of the other two segments as well. If (2) is observed to be true, (1) is certainly true if the unobserved variances are all equal [*i.e.*, $\mathrm{Var}(S_i|K_i = 0)$=$\mathrm{Var}(R_i|K_i = 0)$=$\mathrm{Var}(C_i|K_i = 0)$], and the unobserved means equal the observed means [$\mathrm{E}(S_i|K_i = 1) = \mathrm{E}(S_i|K_i = 0)$, $\mathrm{E}(R_i|K_i = 1) = \mathrm{E}(R_i|K_i = 0)$, and $\mathrm{E}(C_i|K_i = 1) = \mathrm{E}(C_i|K_i = 0)$]. These assumptions are too far-fetched to be credible.

It is reasonable to believe that if the swimming segment is tripled, participation among swimmers would increase. It is also likely that they would be worse cyclists on average than those who are already participating [$\mathrm{E}(C_i|K_i = 0) > \mathrm{E}(C_i|K_i = 1)$] and so $\mathrm{Var}(C_i|K_i = 1)$ would increase. How much it would increase is unknown, and cannot be known until we see how changing the race proportions changes the participation rates from various subpopulations of athletes. Perhaps it would increase it enough to counteract the variance shrinkage that will occur from shortening the cycling distance.

List of figures


Equilateral
Iron Man
100
75
50
25
0
Distance
(kilometers)
Cycling
Equilateral
Olympic
Running
Swimming
0
30
60
90
120
World Record Time for Individual Legs
(minutes)