OPTIMUM SPEED DISTRIBUTION IN 800M AND TRAINING IMPLICATIONS

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Summary

This paper establishes that there is a pace distribution for the 800m that will result in an athlete's fastest possible time. It is one of deceleration through successive 200m segments, and of course the pace of the first 200 and the rate of deceleration are critical. Scientific reasoning and historical evidence are called upon to determine what these should be. Variations necessitated by race situations are discussed. The athlete must have certain attributes in order to be able to produce the required pace distribution, and these attributes need training. The training required to develop these attributes is discussed.

Introduction

The 800m is a fascinating event, in the author's opinion the most fascinating of all. It is unique among the track events in that it uses all three energy systems intensely, and this also makes it complex and challenging to do properly. The three energy systems have different characteristics, particularly regarding pace and capacity, and making optimum use of each of them imposes a pace pattern on the performance. There really is not much variation on this pattern in top performances, though competition type races can necessitate variations, and athletes must be able to cope with these. Even so, such performances, while they can be racing successes, will not be the fastest the athlete is capable of. It will be argued, and rightly, that the ability to race is more important than the ability to run fast, but it is impossible to get away from the need to be able to produce fast times. For the best, fast times will produce records, and for the battler they will produce qualifying times for entry into major races and competitions.

Use of the Energy Systems in the 800m

At the beginning of the race only the creatine phosphate (sometimes known as anaerobic alactic) system is used, because it the only one readily available. The lactic system takes longer to power up, and the aerobic system longer still. Furthermore the creatine phosphate (CP) system is the acceleration system, which the sprinter uses to the utmost to propel himself to maximum speed, and the 800m runner also needs it to accelerate from standstill to his maximum speed for the race. For the 100m runner this system is on the wane after 6-8 seconds, but by more judicious use of it the 800m runner is able to extend the use to 2-3 times this duration. The amount and the duration of the acceleration for the 800m runner will be discussed later in this paper. It is the most powerful system available to the athlete and can make a great contribution to a total 800m performance.

The lactic system is the next to power up and by about the time the runner has finished with his CP system it is available to its maximum extent. It is not as powerful as the CP system, and therefore will not deliver as much speed, but has greater capacity, i.e. it can contribute more energy to the total performance. As will be discussed in the next section, it has a declining output. It lasts longer than the CP system, but eventually it too is completely expended. When it should be expended will be discussed in a later section.

The aerobic system is the slowest to power up, it is the weakest, but it has the highest capacity. That capacity is barely tapped in an 800m, but the system plays the vital role of propping up a fading lactic system. The better the aerobic system the faster the pace it can sustain, and so the more support it can provide to the lactic system. The more the race progresses the greater the proportion of the total power that comes from the aerobic system. A weak aerobic system will cost a runner dearly in the final stages of the race.

Operation of the Lactic Energy System

All energy systems are important in 800m running, but the lactic system provides the key to success. It is the link between the powerful CP system and the enduring aerobic system. A defining characteristic of the lactic system is that its output decreases with use. The longer an effort powered by the lactic system continues, the less the output from the system. It chokes itself off, because the by-product of the operation of the system, lactic acid, inhibits the operation. Eventually the muscles become so saturated with lactic acid that the system is no longer operable. Furthermore not only does the duration of effort bring about a build up of lactic acid, so does the intensity of its use. The faster the pace powered by the lactic system the faster the build up of acid, and the sooner the operation of the system is at an end. It is a matter of fine judgement to pour out the lactic energy at such a rate that it lasts long enough.

We have to distinguish between the maximum available speed under the operation of the lactic system and the speed the system is actually producing. The maximum available speed falls as the build up of lactic acid chokes off the power producing ability of the system. The author has done some mathematical modelling of the lactic system that shows a critical point is reached when the maximum available speed falls to the speed actually being run. At this point the running speed falls sharply, in what a mathematician would call an exponential decline. The equation describing this is reproduced below for those interested.

$$v = v_a + (v_t - v_a)e^{-kt}$$

where v is the actual speed at time t after max available speed falls to running speed
v_a is the speed sustainable by the aerobic system
v_t is the speed (terminal speed) when max available speed equals actual speed
k is a constant.

The above equation describes what every enthusiastic middle distance and 400m runner knows only too well- when the bear jumps on your back, no amount of effort or courage will stop your speed collapsing dramatically.

From the above we know that this point of terminal speed must not be reached before the end of the race. However, not to be near this point by the end means that the lactic system has been under-utilised, and the performance cannot have been optimum. The aim then is to reach terminal speed at the 800m mark.

Basically there are two possibilities for achieving the above. The first is for the entire sector of the run powered by the lactic system, i.e. after the CP system has finished, to be at constant pace, and for this pace to be the terminal speed. The maximum available lactic speed declines linearly throughout the run until at the 800m mark it reaches the constant running speed. The second possibility is for a gradual decline in running speed until at the end it meets the maximum available speed. (The third possibility of an acceleration during the lactic phase is discounted as being impractical- it involves accelerating, decelerating, accelerating.)

Some further mathematical analysis by the author shows that for all runs powered by the lactic system, the optimum strategy is for a deceleration during the lactic phase, rather than constant pace. This is pronounced for the 400m and 800m, but for longer events the theoretical advantage becomes insignificant, and practicalities tend to swamp any possible advantage.

The above two pieces of mathematical analysis of the operation of the lactic system are in yet to be published work by the author.

Some Historical Confirmation of Optimum Strategy

There is some though not conclusive historical evidence that deceleration is the best strategy for fastest time. It is in the form of 22 great performances between 1min 41.73sec and 1min 43.50sec, and they were chosen for no other reasons than that they were available to the author, and they have a first lap/ second lap split. There is no bias in them. There were 51 performances in total in this range known to the author, so 22 represents a reasonable sample, and in is reasonable to regard them as representative of the total, particularly as the story they tell is very consistent.

The first lap and second lap speeds as a percentage of the 800m average speed were determined for each of the 22 performances, and they are shown in the figure below. It will be seen that for 21 of the 22 performances the first lap was faster than the second. The only exception was Steve Cram's win at the Commonwealth Games in 1986. It was a remarkable performance by an athlete who was more a 1500m and mile exponent, and he ran the race that way. Significantly he had two faster performances, both recorded in the graph below, and in both his first lap was faster.

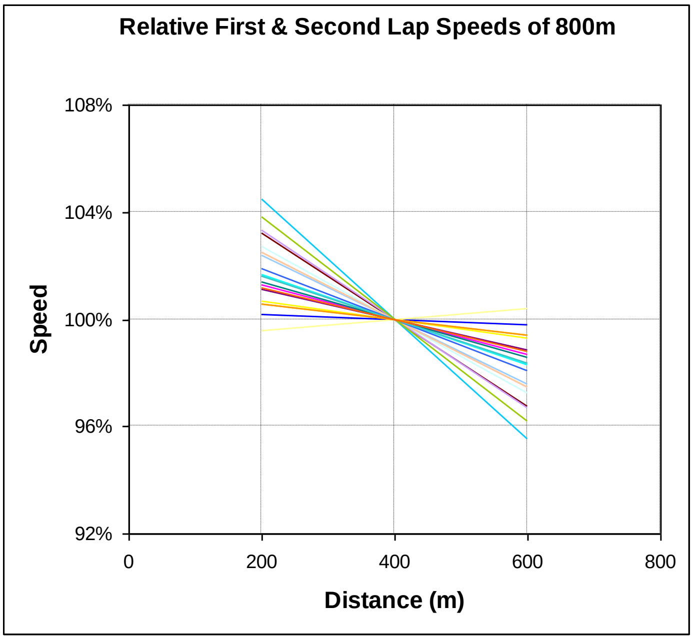

Figure 1 Relative first lap and second lap speeds of 22 outstanding performances.

The average of the first 400m speeds is 101.7%. If Cram's unusual run is omitted the average rises to 101.8%. There is a heavy cluster of performances about this percentage. For a 1mim 43sec performance this means a first lap of 50.6sec and a second lap of 52.4 sec, a differential of 1.8sec. It would seem that if there is an ideal to aim for, it is this 101.8% /98.2% split with respect to the average speed of the goal performance.

The above does not confirm that the lactic phase is one of deceleration, because all of the difference above in the speeds of the two laps could be in the CP phase. However 200m splits from four of the best of the above does provide some confirmation. It is far from conclusive but does point in the right direction. The splits are reproduced in the figure below.

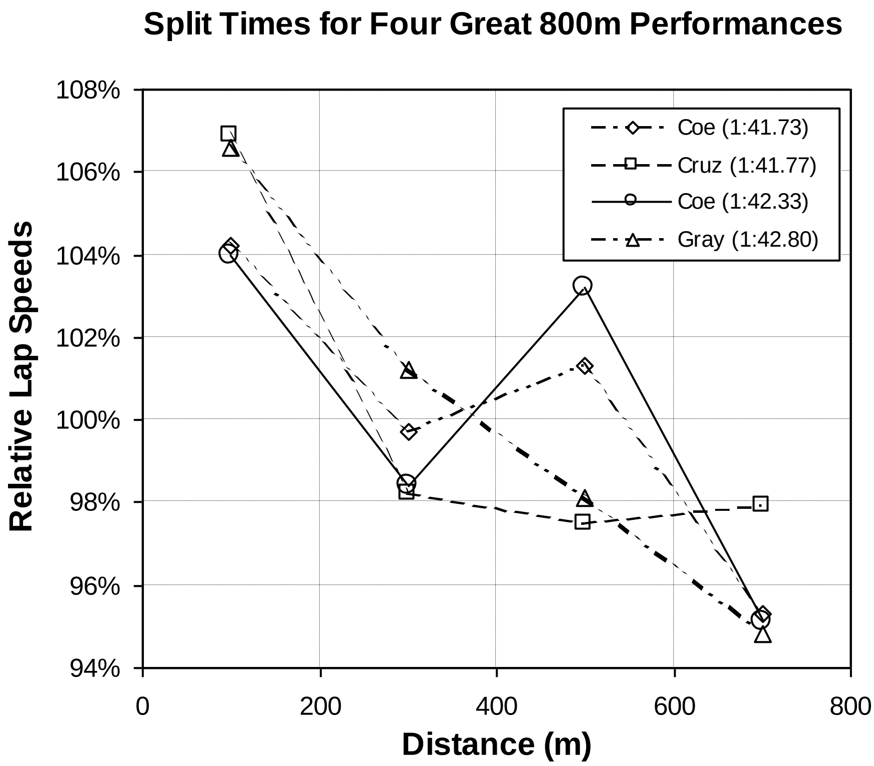

Figure 2 200m splits as percentage of average pace for four great performances

More than the above would be necessary to be able to say something definitive from an historical point of view. However it does suggest that if there was an ideal to which the athletes were running, it was one of a big fall off in speed from the first 200 to the second, a holding operation from the second to the third, and then the inevitable fall from the third to the fourth. The overall trend is certainly one of deceleration from the first 200m, and this is consistent with the first lap/second lap deceleration of the much larger sample. Deceleration throughout the last 600m seems a reasonable ideal on which to base a strategy.

Using the CP Energy System

Now that we know that the optimum strategy for the lactic phase is gradual deceleration throughout, we can determine how to use the CP system to lead into it. The gradual deceleration throughout the lactic phase indicates that the CP system is not required during this phase and it can be expended as much as possible during the first part of the race. How much is as much as possible? Obviously it cannot be anything like a maximum 200m effort.

There are three considerations. The first is that we want the CP effort to last as long as possible, so as to put a lesser requirement on the lactic system. There is evidence that the system can last for much of the first 200m if used judiciously. That means gentler acceleration than in a sprint, holding speed for longer.

The second is that we want good speed, because this is where the cheap gains in overall time are going to come. This is a contradictory demand to the first, because it calls for high acceleration, so some trade-off is necessary.

The third is that when the CP phase is coming to an end and the lactic system is the predominant provider of power, we do not want too high a speed, because the lactic system will not be able to sustain it without a rapid build up of acid.

All of this means that we need an acceleration that is well within the runner's capability. Then he must remain effortlessly near the speed attained for longer than a sprinter remains near his top speed. Perhaps something like 100m is desirable. This is possible if the acceleration has not been severe. Then as the 200m mark is approaching and the CP system is well on the wane it is necessary to ease off, so that the runner is left with a speed that the lactic system can handle.

The logic of all of the above and the experience of international elite 800m runners would suggest that a first 200m time of 88-90% of best possible 200m is the aim. This means that an 800m runner capable of 21.6sec would run the first 200m in 24-24.5 sec. The slower time is probably closer to optimum but circumstances often necessitate the faster effort.

Pace Distribution

As we saw above, the optimum strategy during the lactic phase, which basically is from 200m to 800m, is one of gradual deceleration. A reasonable first pass at a model is one based on a fall in speed of 2% per 200m. This would have the 200m sectors at 88%, 86%, 84% and 82% of best 200m speed. With respect to the average speed based on 800m goal time, the model would be 103%, 101%, 99% and 97%. The 2% per 200m deceleration fits well with twin requirements of beginning with speed that the lactic system can manage and delivering a good yet credible time for the last 600m.

However this is quite conservative with respect to CP performance of elite runners. They tend to go quicker in the first 200m than indicated by the above model. Then they quickly come off that speed and the second 200m is about 5% slower, so they do not get hung up on a pace that the lactic system cannot sustain. Holding to the gradual deceleration strategy, the deceleration from second to third 200 and from third to fourth 200 would be about ¾ % per 200m. A better model in terms of average speed for the goal time is:

first 200	104.50%
second 200	99.25%
third 200	98.50%
fourth 200	97.75%

and in terms of best 200 speed:

first 200	89.00%
second 200	84.50%
third 200	83.75%
fourth 200	83.00%

This model produces the first lap/second lap differential that is the average of the 22 performances above.

A brief mention is necessary about the apparent accuracy of the above percentages. For instance 83.75 seems considerable accuracy, almost 1 in 10,000- more than is possible for a runner to judge. However 83% is not particularly accurate- it has a possible error of 1.25sec in an 800m run. 0.25 is not meant to signify accuracy to the second decimal place, but rather the accuracy entailed in going to the nearest ¼ of a percent. Going down to 0.25% reduces the possible error to 0.3sec in 800m, or about 0.1sec in a 200m sector.

To put the above in context, let us consider a runner aiming to run 1min46sec. The 200m splits according to the model would be:

25.3sec
26.7sec
26.9sec
27.1sec

Before we go on to consider training implications of this pace distribution, it is instructive to look at the best and the worst of pace distribution. This occurred in the one race- the final of the 1988 Olympic 800m. It is shown in the figure below.

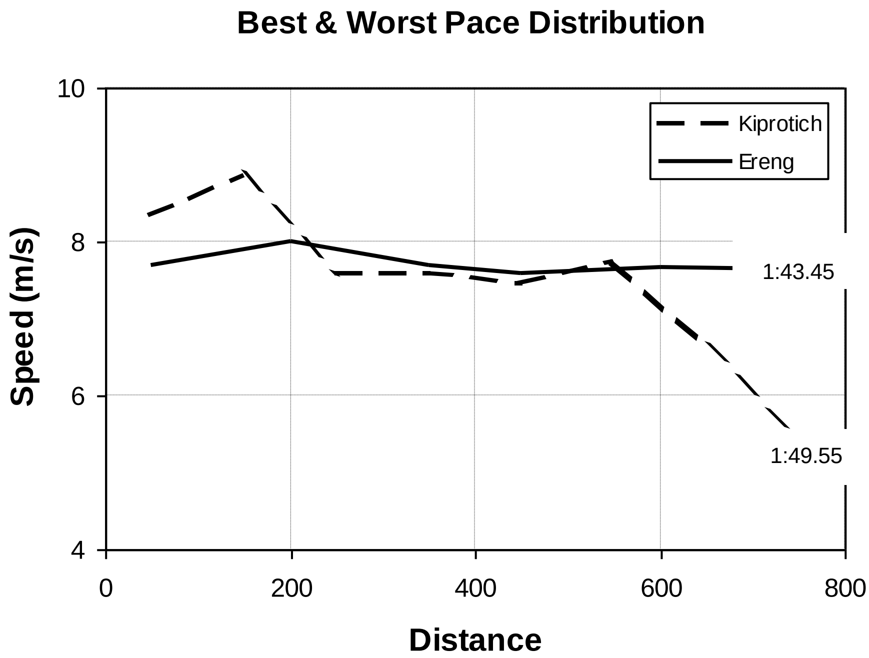

Figure 3 The best and worst of 800m pace distribution

Kiprotich was presumptuous in going out that fast and trying to hang on to the speed. His best going into the Games was more than a second outside the winning time, and he had no significant background in 400m running. It was inevitable that he would accumulate too much lactic acid early and go into dramatic speed collapse well before the finish, and he did. The winner, Paul Ereng was a different story. Like Kiprotich he was a Kenyan but he had gone to a US college as a 400m runner, so he had a good CP system. Nevertheless he was foolhardy in the Kenyan trials and went out far too fast. He went through 400m in 49sec and 600 in 1min 14sec before the inevitable happened. His last 200m took 31 seconds, as he was passed by one, then another runner. He just hung on for third, and a chance to run at the Olympics. However he learnt his lesson well, and his run in the final at Seoul was a model of sensible distribution of energy.

Training implications

<u>THE CP SYSTEM</u>

The model arrived at above has the first 200m at 104.5% of average speed for goal time. Given that life is not perfect and he might have to run faster for position, the runner must be able to run the first 200m at 105%, and this must be comfortable. Indeed we saw above that Cruz and Gray went at 106%, but perhaps this is not something to be copied by lesser mortals until 105% is mastered. 105% can only be comfortable if it has insignificant lactic content, so it must be a CP effort. The system must last for most of the 200m, and it must deliver a speed that is 105% of goal average pace. That requires some training.

If we look at 1min46sec as the goal time (providing it is not a presumptuous goal), the average 200m speed is 26.5sec. This requires the athlete to be able to run the first 200m comfortably in 25.2sec. The comfort margin will be provided by the athlete being capable of 22.5-22.7sec for 200m. This is in conformity with the speed implied in the model in terms of 200m capability (89% for first 200). Such running is quality speed- it is about 92% of a 200m performance of comparable standard to 1min 46sec. An 800m runner will need to train for it. It is the same at every other level of performance- the first 200m requires the athlete to be well equipped for speed relative to that level.

The first requirement is to improve maximum speed. We want to increase the stores of creatine phosphate in the muscles, and we do this by stressing the system that uses them. This stress is provided by full speed sprint work, like flying 60m repetitions. When the stores are increased, i.e. when the speed is good, we do something about lengthening it. This is another way of saying that we cannot have speed endurance unless we have speed. The lengthening is accomplished by moving the distance out to 100 then 150m. All the while the emphasis is on the efforts being smooth and relaxed. When long speed has been well developed it is time to move on to 200m repetitions. These should be slightly faster than the 105% of goal average pace, say about 110%, so that 105% will come easily. The repetitions should be relaxed, not flat-out, and the athlete should be still full of running at the end of each. They should become second nature, so that the right speed for the first 200m of the race comes quite naturally. After the preparation outlined here this will be quite possible.

<u>THE AEROBIC SYSTEM</u>

The aerobic system does not work by itself in a properly run 800m, and it is not the predominant energy system. None the less it is vital, and it must be a good system. The difference $(v - v_a)$, where v is instantaneous running speed and v_a is the maximum speed the aerobic system alone can sustain, is very important. It determines the amount of lactic acid produced. Obviously for a given speed v, the higher v_a the less acid produced and the longer the lactic system lasts. The 800m runner needs a high value of v_a, and cannot ignore this aspect of preparation.

The way to increase v_a is to do long continuous runs at very slightly above maximum steady state pace. Maximum steady state pace is about marathon pace, so a little faster is not very fast and can be continued for some time- 45 min. to 1 hour would be reasonable. Having the pace just above maximum steady state pace stresses the body a little but manageably, and causes it to adapt so that it can handle the pace in steady state mode. Thus v_a has been lifted.

A fundamental factor driving the aerobic system can also be improved, and from that will come an increased v_a. That factor is the amount of oxygen the lungs can take in, and it is known as the maximum oxygen uptake. Obviously the more this is, the greater the rate at which glycogen can be consumed and the greater the power from the aerobic system. A maximum effort of 6-10 minutes achieves the maximum oxygen uptake. A typical session would be 2-3x3km with jog recoveries of similar duration. The speed is above maximum steady state pace, but not appreciably, so the accumulation of lactic acid is not great and jogs of this duration will be sufficient to allow repeats of the same quality. Progress is by continual small increases in the speed of the runs.

THE LACTIC SYSTEM

The performance we want from the lactic system is to sustain the effort for 75-90 seconds (depending on standard), allowing only a modest drop off in speed. The speed we want from the system, according to the model, is 99.25%, 98.5% and 97.75% of goal average pace for the second third and four 200m sectors. Put less accurately but more realistically, we want 600m at slightly less than the average goal speed for 800m, sliding from a few tens of a second above the pace for the first 200m to a few tenths below for the last 200m. This requires a well developed lactic system.

As with any of the energy systems, there are two aspects- power and capacity. The first determines how fast and the second how much, or how long. The faster the speed available from the lactic system the higher running speed can be without the athlete reaching speed collapse before the finish. So we are interested in developing a powerful lactic system. This is achieved by doing very fast 300m repetitions with as much recovery as possible. The first part of each repetition exercises the CP rather than the lactic system, but there is no way of avoiding this.

Capacity of the lactic system is even more important than its power, because the system must last to the finish. One way this can be developed is by extension of the above 300m session. 5x300 becomes 4x400, then 3x500 and finally 2x600. From a good speed base the athlete gradually drops his speed and extends the distance. As with the 300s, there is a problem in that the effort is aided by the CP system in the early part of the repetition. There is no way the CP component can be taken out. To compensate for this the repetitions should be faster than the lactic system would deliver. So the 600s should be above goal average pace. For instance for a 1min 46sec runner, for whom goal pace would be 1min 19.5sec, a challenging but reasonable target would be two 600s averaging under 1min 19sec.

There is a way of removing the assistance provided by the CP system, and thus making the lactic system work harder. This is by means of sets of 3x300 with very short recoveries within the set. If the recoveries are less than three minutes the CP stores in the muscles are not completely replenished. The second and third 300 are run with only partial replenishment of CP, and there is more demand on the lactic system. The idea is to run the first 300m at the pace of the first 300m of an 800m, and the second and third at the sliding pace of the last 600m. Recoveries could start at 2 minutes, and progression would be by shortening recoveries.

Conclusion

By looking at the 800m event from a theoretical and historical perspective, we are able to see the requirements on the three energy systems and consequently the optimum pace structure of the event. This leads us to decide the essential training elements for the event.