Fatigue Series: Introduction

29 Apr 2008
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Category: Fatigue/Central Governor, Series
exercise physiology

Introducing a new series: The mystery of fatigue and the limits to performance

Here's one of the million dollar questions in sports sciences today: **How is it possible for a 10km runner to SPEED UP in the final 400m of his race?** And if he had that "reserve capacity" all along, **why did he not speed up 800m before the end? Or 2km? The whole way?**

As you read that, you're probably thinking "Big deal, what a ridiculous question. It's obvious that you can't speed up, because….um, well, you see, it's the….why was that again?"

And now, physiologically speaking, you are stuck. Because the reality is that there is **no *single* physiological theory** that can properly explain why athletes pace themselves the way they do, why fatigue happens and what limits performance. There is no book, no proof, no all-knowing scientist who can tell you the answer to this, the most seemingly basic question in the field! As you read this, there's a good chance you're simply dismissing the question as obvious – "It's experience and training, a conscious decision". And I agree with you, but we still haven't explained the physiology of how this decision was made.

It's become something of a mantra here, but the truth is that **if anyone tells you they KNOW the answer, they're lying, or ignorant, or both**. Because years of research has failed to answer that question definitively. There are theories, yes, and some do explain fatigue under very specific conditions quite well. But to this day, no one really knows the answer to the simple question posed above.

And before you get your hopes up, we're not going to tell you the answer either! Because we don't know it! But we do know is what it's NOT, and we'll discuss that. And as mentioned, there are theories, some new, some old, which do partly explain performance limits, and we can discuss those. And we can introduce the great unknowns, and hopefully make sense of some of the myths and fallacies that are thrown around concerning fatigue, performance and human exercise limits.

And so with that, we **introduce a brand new series** here on the Science of Sport. We'll call it **Fatigue, pacing strategies and the limits to performance**.

It will look at the following:

Theories for fatigue – what causes fatigue and limits exercise performance?
Pacing strategies – a basic observation with a complex cause
Exercise at the "extremes" – exercise in the heat, and at altitude
Deceiving yourself – how false information about time and distance influences performance
What happens during **sprint events**? And how is pacing different from endurance events?
The **anticipatory regulation of exercise**: A proposed model for performance using the **Perception of Effort**

We are ultimately heading for that last instalment of the series – a new model for how exercise performance is regulated. That model was actually produced as the concluding section of my (Ross's) PhD thesis, so this series is a personal one for me, and basically a summary of my PhD. I hope it will be as interesting to read as I know it will be rewarding to write. *(Incidentally, the model and review is also in review for publication in a scientific journal as you read this, so hopefully in a short while, it'll be out as an academic text as well, for those who are interested.)*

The theories – it must be anaerobic lactate production: your muscles are fatigued

There are those who'll try to answer our "simple question" from above. Textbooks will tell you that you slow down because you run out of oxygen, you become anaerobic, lactate forms and "poisons" the muscles, or you get too hot and your brain says "stop!" The books explain how muscle becomes fatigued as a result of these chemicals that build up, caused by a lack of oxygen delivery as you get closer to the VO2max, where you can't use any more oxygen.

And maybe this is true. . .but hang on, that **doesn't explain how you SPEED UP in the last 400m**. Remember, in a 10km race, you're running quite a lot faster than your "anaerobic threshhold", which is always defined as the speed/intensity above which you start to accumulate lactate. So one thing we do know, is that **in a 10km race, with 1km to go, there's a lot of lactate in the system**! Similarly, you can be pretty much guaranteed that with 1km to run, the calcium channels are at their most leaky, the phosphate and H+ ions are at their peak, and the body temperature is at its highest.

Now think about it for a moment – if your muscles are becoming weaker and weaker because of chemicals like lactate, or a lack of oxygen, then how is it possible to get FASTER at the end of the race? **The end of the race?** That's when the lactate levels are the highest! Oxygen levels are the lowest, because for 40 minutes, you've been running yourself into what those textbooks call "oxygen debt," right? Well, if that's true, then the **only thing that would happen is that you would get slower and slower and slower**.

Instead, you speed up at the end. Added to this, there's a growing body of evidence that lactate is not the "bad guy" it was once made out to be, maybe it's even the "good guy." We'll look at that as well in the coming weeks.

But this, in a nutshell, is one of the theories for fatigue. It's been called the "Peripheral fatigue model", the "Cardiovascular/anaerobic model", and the "Catastrophe model" (all by Prof Tim Noakes – more on that lower down), but what it is basically saying is the following:

Fatigue is the result of failure – something in the physiology fails, causing the athlete to

stop or to slow down
That failure can be anywhere in the system – it might be **failure to supply enough oxygen** to the muscles, **failure to keep lactate**, phosphate or hydrogen **ion levels down**, a **depletion of glycogen**, or **failure to lose heat**, causing the body temperature to rise too high
Once this "failure point" is reached, exercise must slow down, or stop altogether. The fatigue is the result of the failure – it's a "catastrophe"

The key point is that fatigue is a "limit," and it lies in the muscles or the complete inability of the brain to activate muscle

The other extreme – there's no muscle fatigue, it's all in the brain

On the other end of the spectrum lies the so-called "**Central Governor**" theory. This theory was developed by Prof Tim Noakes, under whose supervision both Jonathan and I both did our PhDs. In fact, my PhD was titled "Anticipatory regulation of performance" and it examined the very question I asked at the beginning of this post.

Essentially, this theory, which I'll rather called "Anticipatory Regulation" for reasons that will become clear further down, holds that:

During exercise, the **brain regulates performance to balance** all the body's physiological systems
Fatigue (or the slowing down in pace) is the **result of this regulation**, which happens **BEFORE** any physiological "failure" can occur
Therefore, rather than slowing down AS A RESULT of lack of oxygen, high body temperatures, high lactate levels etc., you slow down IN ORDER TO PREVENT THEM.

Notice that key difference – **performance and fatigue are regulated to prevent the potentially harmful limits from being reached**. These "limits" to exercise are real. If your body temperature is above 41 degrees, you'd stop and be in serious trouble. If you did accumulate too much hydrogen, it would be bad news. But when exercise takes place, they don't happen because the brain is in control, and it regulates the body specifically to protect against that damage. At the same time, it's trying to balance protection with your own desire to perform as well as you can, and that produces a constant balance between two potentially conflicting goals.

In this theory, then, you get what is called a "pacing strategy," which is the output by the muscles, as part of this regulation. **Performance is regulated, not determined, by the physiology**.

It's all in the timing – when do you slow down?

If you want tangible proof of this, think of the following hypothetical situation:

Let's say you run a 10km race at sea-level, and in cool temperatures. Your **time is 40 minutes, giving you a speed of 4min/km**.

Now, let's say I transport you instantaneously to the following two places:

1. **Halfway up Mount Everest**, an altitude of about 4000 m
2. The **middle of Beijing in the summer time**, where it's 35 degrees, and humidity is 60%.

Now, I make you run that same 10km race. What is going to happen? I'm sure that all of you are in agreement that your time of 40 minutes is under threat! You might be lucky to crack 42 minutes in these "extreme" conditions. But here's **the million dollar question** (another one!):

When do you first slow down?

Do you:

a. Start off at 4 min/km, running the first 5km in 20 minutes, before you suddenly find that you're forced to slow down, because you're suddenly gasping for air at altitude, or because you're incredibly hot and feel close to collapsing?; or…
b. Start off much slower than normal, because you KNOW that if you don't, you'll be in trouble after 5km? Within the first 30 seconds of your run, you have already "decided" to slow down. Perhaps you start off at 4:20 min/km, and manage to hold that pace for a while, then you get slower and slower, until the final kilometer, when you can speed up again?

I'm sure that everyone who has ever run in the heat or at altitude can relate to the fact that the answer is b) – you start slowly. In fact, it takes probably less than 20 seconds for your body to "decide" to run more slowly than usual. Now, you have to ask yourself:

How do I know to adopt a different pacing strategy in these conditions?

Remember, it happens so early that nothing is different, except for your sensation that it's either hotter or that the air is thinner – that sensation then, seems to be key. But it can't be that you are already overheating within the first 30 seconds, or even two minutes of your run. You can't already be in oxygen debt at altitude? So how, then, do you "decide" to slow down? Once again, some will dismiss this as obvious, but I'd challenge you to find the answer to this question in a physiology textbook – you can't because it doesn't exist. The book is going to tell you that you slow down because of anaerobiosis, oxygen debt, lactate accumulation. But there's no evidence for it.

A controversial model

– BUT THIS IS NOT A SERIES AIMED AT GLORIFYING ANY MODEL

Now, the Central Governor model is highly controversial, both within the academic world, and among the public who've heard of it, in some form. It's one of the most divisive theories around, because it lies so far to the extreme opposite end of the spectrum compared to the other, "textbook" model(s) for fatigue. The Model has, over the years, been twisted, mis-interpreted, bashed, criticised, hyped, glorified and dismissed in equal measure – for example, it's the subject of a 40-page discussion thread on LetsRun.com, which would take all year to summarize! Part of the problem has been that people read Tim Noakes' work from the late 1990′s and 2000, and don't look at the more recent work, and the evidence that has been gathered since.

But perhaps the biggest problem is that **the "governor" has been wrongly portrayed**

(sometimes deliberately by the people who created it, to its detriment, I might add) as a little "black box", that 'magically' controls our physiology and performance. In this concept, the term "Governor" conjures up images of a school headmaster or a little green Martian enforcing control over your exercise, and represents a misunderstanding of the theory.

People have tried to personify the concept, and pinpoint its location in the brain, when in fact it's the concept that counts, and it doesn't need to exist as a specific location. For that reason, **we'll steer clear of the term "Governor",** and go instead with "***Anticipatory Regulation***". Also, as knowledge is evolving, the term needs to be more all-encompassing. Hopefully, we can translate some of this evidence in this series…

Fatigue is not all in the mind!

But let me reassure all the sceptics out there – **I'm not going to write this series as a one-dimensional glorification of the Central Governor theory**, so don't sharpen your knives (just yet!). For while I studied the regulation of exercise by the brain and am fully behind the concept that exercise is regulated (not limited) in anticipation of a limit, there are physiological and performance findings that the theory cannot explain. It is not, therefore, the single answer we are looking for. It needs critical and thorough analysis, and ultimately, the trick will be to balance the two extremes.

And let me say this now, with the hope of never repeating it: **Fatigue is not all in the mind**! This misconception, which has unfortunately been propagated by academics and media and the public, is best forgotten at this early stage. **Fatigue and the limits to performance are NOT simply mental barriers**, and "mind over matter" is a massive oversimplification of the truth! Having said that, mental strength and willpower are key factors, part of the answer, but **they never beat physiology**. We'll look at the role of willpower, self-belief and mental strength in this series, but I repeat "It's not all in the mind!" The analogy is that "you cannot commit suicide by holding your breath," and the same goes for exercise: physiology wins the day, every day!

The real answer, then, is **likely to lie somewhere between these two extremes** – a combination of the "Anticipatory Regulation" model and the "Peripheral Fatigue Model".

Physiology wins the day, every day!

We'll work towards that answer over the next few weeks. It is an enormously complex and detailed area to tackle, but we'll jazz it up and try to make it entertaining as much as possible! It may take up to a month to get through it all, and we will carry on with our normal news stories and other features between installments.

As usual, comments and feedback are welcome! But bear in mind, we're working towards the answer, so if you feel we've left something out of each post, it might be coming in the future!

Join us again soon!
Ross