Thomas Kuhn's 'Structure of Scientific Revolutions' applied to exercise science paradigm shifts: Example including the Central Governor Model

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Thomas Kuhn's 'Structure of Scientific Revolutions' applied to exercise science paradigm shifts: example including the Central Governor Model

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ABSTRACT

According to Thomas Kuhn, the scientific progress of any discipline could be distinguished by a pre-paradigm phase, a normal science phase and a revolution phase. The science advances when a scientific revolution takes place after silent period of normal science and the scientific community moves ahead to a paradigm shift. I suggest there has been a recent change of course in the direction of the exercise science. According to the 'current paradigm', exercise would be probably limited by alterations in either central command or peripheral skeletal muscles, and fatigue would be developed in a task-dependent manner. Instead, the central governor model (GCM) has proposed that all forms of exercise are centrally-regulated, the central nervous system would calculate the metabolic cost required to complete a task in order to avoid catastrophic body failure. Some have criticized the CGM and supported the traditional interpretation, but recently the scientific community appears to have begun an intellectual trajectory to accept this theory. First, the increased number of citations of articles that have supported the CGM could indicate that the community has changed the focus. Second, relevant journals have devoted special editions to promote the debate on subjects challenged by the CGM. Finally, scientists from different fields have recognized mechanisms included in the CGM to understand the exercise limits. Given the importance of the scientific community in demarcating a Kuhnian paradigm shift, I suggest that these three aspects could indicate an increased acceptance of a centrally-regulated effort model, to understand the limits of exercise.

Many *BJSM* readers will have heard of, but not read, Thomas Kuhn's 'The Structure of Scientific Revolutions' (more than 57 000 citations). To summarise the key message, the Kuhnian model argues that science does not progress through slow accretion of data but in revolutions. Originated in rational or irrational bases, a scientific revolution takes place when a new pattern of thought emerges.[1] Thomas Kuhn, who died in 1996, used the astronomy as an example—when the Copernican theory replaced the Ptolemaic theory. Yet, no example of 'paradigm shifts' (a phrase he coined) has been provided for sports science. The purpose of this short essay is to argue that a 2012 revision could now include valuable illustrations from our field. I will focus on the 'central governor model (CGM)' simply as a primary example because of the very high citation rate received by that paradigm and its multidisciplinary relevance to numerous sports sciences.

According to the Kuhnian philosophy, the scientific progress of any discipline could be distinguished by a preparadigm phase (I), a normal science phase (II) and then the revolution phase (III).[1 2] Although the 'normal science phase' contains observations that do not fit the current paradigm, scientists will not abandon the existing belief while there is no credible alternative (phase II). The 'anomalous' observations may be dismissed as error.[1 2] However, the anomalies may accumulate and create a 'crisis' which approaches to a scientific revolution (phase III). Then, bolder scientists explore alternatives to traditional assumptions, while the majority of the community opposes conceptual changes. The community moves ahead to a paradigm shift when the challenging theory is solidified.[2] Therefore, the science advances when a scientific revolution takes place after silent period of normal science.

HAS THERE BEEN A REVOLUTION IN MODERN EXERCISE SCIENCE?

I suggest that there has been a recent change of course in the direction of the exercise science. A core prediction of the traditional model of exercise is that either central or peripheral mechanisms determine the development of fatigue in a task-dependent manner.[3 4] The exercise would be probably limited by alterations in either central command or peripheral skeletal muscles.[3–5] The nature of the task to be performed would determine which factors limit the performance as not all mechanism will be involved to the same extent in every fatiguing task.[3] This interpretation has provided the 'current paradigm' in the exercise sciences for the past century.[6]

Instead, the CGM suggested by Professor Tim Noakes and colleagues has proposed that all forms of exercise are centrally regulated.[7–9] According to this model, the central nervous system (CNS) subconsciously calculates the metabolic cost required to complete a task in order to avoid catastrophic body failure. In all forms of exercise the CNS would regulate the extent of neuromuscular recruitment, anticipatively and continuously, according to changes in muscles, joints, body temperature, cardiopulmonary system and cognitive process.[7 10–12] Rather than a central fatigue model as otherwise interpreted,[4] the CGM explains how exercise is regulated.

Some have criticised the CGM and supported the traditional interpretation.[4 13 14] In fact, the resistance in accepting new ideas is consistent with Kuhn's description, as most in the scientific community continue to believe the current paradigm.[1] Although the traditional model has been constantly challenged, inconvenient findings (or anomalies)

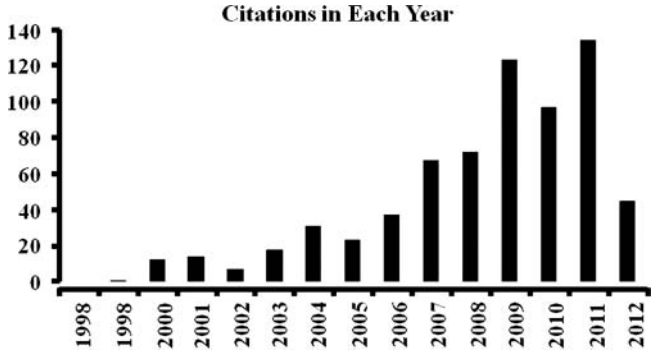

Figure 1 Citation report having 'central governor and exercise' as truncate keywords (accessed by http://www.webofknowledge.com on 24 April 2012).

have been ignored by defenders of the traditional paradigm for decades (phase II).[15–19] Yet, the Kuhnian 'crisis' appears to have emerged as two papers exposed anomalous evidence systematically.[10 20] After a series that consistently presented a centrally regulated effort model, the CGM,[10–12 20 21] the scientific community has begun an intellectual trajectory suggesting a growing acceptance of this theory (phase III).

INCREASED ACCEPTANCE OF A CENTRALLY REGULATED EFFORT MODEL

Given the impossibility of performing neutral comparisons with standardised rules, to determine the truth of a theory (which Kuhn labelled as 'incommensurability of theories'), collective judgement is an important criterion to decide between rival theories in the Kuhnian process. The scientific community would demarcate not only the current paradigm, but also an eventual paradigm shift during which old concepts are replaced by new interpretations.[1 2] Three aspects could indicate a collective judgement inclined to a paradigm shift with the acceptance of a new interpretation in exercise sciences.

(1) *Number of citations*: First, the number of citations about a specific theme could indicate the focus of a particular scientific community along time. A Web of Science search for 'central governor and exercise' as keywords suggests a rising interest in subjects earlier challenged by the CGM. After the embryonic suggestion of the CGM,[22] this theme has been cited 590 times by studies not authored by the originators of this concept. Studies have cited this theme around 118 times a year during the last 3 years (figure 1). In this case, it is necessary to assume 'central governor and exercise' as representative keywords of the CGM, not including studies which have used different keywords to deal with the same model of exercise.[19 23 24] A search delimited on papers that have formally proposed the CGM shows a substantial interest by the exercise physiology community in this subject. Together, two papers of the series have been cited more than 330 times excluding self-citations (figure 2).[10 21] A recent paper on the CGM,[25] published by an important website, has been viewed more than 1830 times. Other publications have been viewed more than 6600 times.

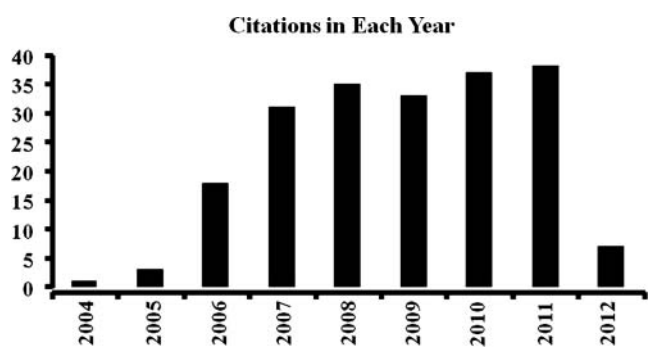

Figure 2 Citation report of two articles[10 21] proposing the central governor model (accessed by http://www.webofknowledge.com on 24 April 2012).

(2) *Increased debate on issues challenged by the CGM*: Second, traditional journals of exercise physiology have published special editions to promote the debate. For example, the *Journal of Applied Physiology* published specific contents about fatigue mechanisms during exercise (104; 2008), highlighting central mechanisms that could be involved in the exercise regulation. The *BJSM* published a series of articles which could support the CGM (46; 2012), including studies that challenged the traditional concept of VO_{2MAX}[26 27] or suggested a probable central regulation during exercise.[28] Also, reviews, letters and rebuttals have added more focus on this topic.[29–33]

(3) *Incorporation of a new interpretation by the Scientific Community*: Perhaps, the most relevant is that scientists from different fields have highlighted mechanisms included in the CGM to understand the limits of exercise.[5 29 34 35] Researchers investigating fatigue mechanisms have recognised that neither peripheral[5] nor central[35] mechanisms would explain the exercise limits in isolation. As stated by Professor Mark Hargreaves, University of Melbourne, 'Having spent my professional life studying various aspects of skeletal muscle metabolism, my bias remains with the skeletal muscles as being 'central' to fatigue and exercise limitation. That said impaired exercise performance under hot environmental conditions, in the absence of significant changes in peripheral biomarkers of fatigue, requires me to consider a more complex regulatory process. Thus, advances in our understanding of fatigue and exercise limitation in humans require complex experiments that probe the fundamental neurobiology underlying the interactions between central motor drive and skeletal muscle'. Indeed, studies have demonstrated changes in performance by non-metabolic compounds such as carbohydrate rinse and caffeine placebo, suggesting some cerebral regulation of the exercise.[36–38]

As someone trained in the philosophy of science, I contend that we are witnessing an example of science—in this case exercise science—following a pattern consistent with the Kuhnian model of scientific discovery.[7] What may prove to be a scientific revolution began as a natural consequence of accumulated anomalous findings. In the presence of these inconvenient findings, new ideas created the 'crisis' that promoted a scientific revolution in exercise sciences—what Kuhn referred to as a paradigm shift. The CGM may have boosted an increase acceptance of a new interpretation, a centrally regulated effort model, to understand the exercise limits. Recent reviews have incorporated this model to explain the factors regulating the exercise performance.[39 40]

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