Institution: Aberystwyth University

Unit of Assessment: 26 (Sport and Exercise Sciences, Leisure and Tourism)

Title of case study: Development of a performance-enhancing warm-up procedure for athletic events

1. Summary of the impact (indicative maximum 100 words)

The Human Performance Research Group at Aberystwyth University developed a novel high-intensity "warm-up" regime, known as "priming exercise". Performing this type of exercise can provide an ergogenic effect during subsequent exercise or competition. This research has impacted upon professional practice of sports scientists and coaches tasked with preparing elite athletes for competition. Specifically, previously warm-up exercise was performed prior to exercise, whereas now many practitioners apply priming exercise regimes. In addition, this practice has a direct impact upon the performance of both elite and amateur athletes.

2. Underpinning research (indicative maximum 500 words)

Overview of the research conducted:

This body of research was primarily undertaken to better understand the metabolic processes that occur at the onset of exercise, rather than to directly identify an ergogenic "warm-up" protocol. This research established that "high-intensity" priming exercise (that significantly increases blood lactate concentration) increases the primary amplitude of the oxygen uptake response in the muscle consequent not to a "warm-up" effect *per se*, but rather to an increase in muscle activity (Burnley et al., 2002). This increase in muscle activation enhances the muscles ability to utilize oxygen, leading to an increase in exercise performance (Jones et al., 2003; Burnley et al., 2005). Jones et al. (2003) demonstrated that prior heavy exercise resulted in an elevated blood lactate concentration and enhanced subsequent performance (measured as time to exhaustion during cycle ergometry) by 30-60%. Burnley et al. (2005) performed a more comprehensive investigation and showed that both prior moderate and prior heavy exercise increased mean power output during a cycle performance trial by 2-3%. The findings of this research fly in the face of traditional thinking – that the muscle must be "warm" to perform optimally, and that an increase in blood lactate concentration has a negative effect on subsequent exercise. This research clearly shows that elevating blood lactate concentration (to~4mM) with a short (~6 min) bout "priming exercise" (performed ~20-45 min prior to exercise), can dramatically enhance exercise performance.

This research has impacted upon athletes and practitioners as it has provided key evidence that overturns previous beliefs about "warm-up", and it provides an alternative "priming protocol" that that can clearly enhance exercise performance. This effect is likely most effective during "shorter" (~2-15 min) bouts of exercise performed within the laboratory, but would likely be of benefit during competitive events of up to a few hours in duration.

Outline of underpinning research: what was undertaken, when, by whom:

The research underpinning this case study was conducted by the Human Performance research group at Aberystwyth University, led by Dr Mark Burnley (2002-2012; now University of Kent) and with colleagues at Aberystwyth University; Prof. Jonathan Doust (2002-2006; now University of Brighton), Dr Jonathan Baker (2007-present), Dr Glen Davison (2006-2011; now University of Kent), and in collaboration and with Prof. Andrew Jones (University of Exeter).

3. References to the research (indicative maximum of six references)

Peer-reviewed literature:

1. Burnley, M., Doust, J.H., Ball, D. & Jones, A.M. (2002). Effects of prior heavy exercise on VO_2 kinetics during heavy exercise are related to changes in muscle activity. *Journal of Applied Physiology* **93**, 167-174.
DOI: 10.1152/japplphysiol.01217.2001
2. Jones, A.M., Wilkerson, D.P., Burnley, M. & Koppo, K. (2003). Prior heavy exercise enhances performance during subsequent perimaximal exercise. *Medicine and Science in Sports and Exercise* **35**, 2085-2092.
DOI: 10.1249/01.MSS.0000099108.55944.C4
3. Burnley, M., Doust, J.H. & Jones, A.M. (2005). Effects of prior warm-up regime on severe intensity cycling performance. *Medicine and Science in Sports and Exercise* **37**, 838-845.
DOI: 10.1249/01.MSS.0000162617.18250.77
4. Burnley, M., Doust, J.H. & Jones, A.M. (2006). Time required for the restoration of normal heavy exercise VO_2 kinetics following prior heavy exercise. *Journal of Applied Physiology*, **101**, 1320-1327.
DOI: 10.1152/japplphysiol.00475.2006
5. Burnley, M., Davison, G. & Baker, J.R. (2011) Effects of priming exercise on VO_2 kinetics and the power-duration relationship. *Medicine and Science in Sports and Exercise*, **43**, 2171-2179.
DOI: 10.1249/MSS.0b013e31821ff26d [REF2 submitted]

4. Details of the impact (indicative maximum 750 words)

Warm-up exercise has an important role to play in optimising performance during subsequent exercise. Prior to this body of research, pre-competition activity was undertaken, in part, to warm the muscles prior to the event. Research conducted at Aberystwyth University showed clearly that rather than an increase in muscle temperature, it is a change in muscle activation that leads to the ergogenic effect observed. This research provided key evidence in the development of "priming" exercise regimes for use prior to athletic competition.

Within this impact case study we are claiming two forms of impact. First, the impact upon the professional practice of sports scientists, coaches, and elite athletes who now employ priming exercise regimes (in the place of other "warm-up" exercise) with prior to competition. Specifically, the examples below show impacts upon the English Institute of Sport (EIS), Team Sky professional cycling team, a professional UK based cyclist. It is likely that others will have been impacted, and those discussed are not a conclusive list. Secondary impact is claimed from the dissemination of this work to amateur athletes and the wider exerciser community. This was an impact upon society, and in particular, informing their behaviours.

Impact upon sports science practitioners and elite athletes

The key difficulty in "proving" impact within elite sport where the differences in performance are miniscule, and the reward for success is huge, is that the precise practice of practitioners and elite athletes are closely guarded secrets. Whilst investigating the impact of this research it became evident that there was a disconnect between the "research" and its "application" within sport. It was clear from the research that there was a significant benefit of priming exercise within the laboratory, but these benefits were potentially not realised by sports scientists and their athletes.

Example 1 – English Institute of Sport (source 1)

The head of physiology at the English Institute Sport (EIS) was clearly influenced by the work on priming exercise of Dr Mark Burnley and investigated the warm-up practices performed by elite UK athletes and found that similar protocols were performed by sprinters all the way through to marathon runners. He questioned this approach and presented an alternative – priming exercise. This was met with resistance by coaches and athletes alike – maybe unfairly, they suggested that "your evidence is circumspect so this is off limits" and "we don't want to spend all of our pennies in the warm-up for fear that they would suffer in the main performance".

During a relaxed phase between competitions, Dr Ingham and colleagues (with the backing of UK Sport) conducted applied work using an adapted "high-intensity" priming protocol, based on our research, and found a 1 s (0.8%; or 6 m) improvement in running performance in a group of elite 800m runners. The majority of this performance improvement came in the final 400m, where the pace slowed less than the control.

This new priming protocol was on first glance similar to what athletes previously performed, but contained a "competition specific protocol" which elicited a marked improvement in performance. This testing using elite athletes and a competition specific strategy brought the breakthrough in application, which was fuelled from the research. This has now been infused into the systems at EIS and their long-term strategy. EIS network fed this practice to other physiologists and to other "engine room sports" such as swimming, cycling and rowing and was used at the Beijing Olympics and other major championships since.

Example 2 – Professional cycling (sources 2 and 3)

Our second example covers the use of priming exercise within professional cycling. An interview broadcast live on ITV4 with a UK based professional cyclist (riding for the metaltek_KOO professional cycling team). The protocol performed prior to competition was based upon knowledge learned from research performed at Aberystwyth University, and mentions that his goal is to "prime the muscles for the race". Interestingly, he also states a negative effect of not performing priming exercise prior to competition.

Further to this interview we provide a youtube clip that shows a performance coach for the Sky pro-cycling team talking about their warm-up procedures prior to time-trial events (source 3.1). The specific details of their practice are shown in a screenshot taken from the clip (source 3.2). This shows a "progressive" 8 min warm up", a number of short accelerations to "activate" [the muscle fibres], and the instruction to finish the protocol "10 minutes before the start of competition". It is very clear that their practice is based upon the priming exercise literature. They also state the usefulness of this practice across a range of event distances, and that its use is also applicable to amateur athletes.

Wider dissemination / impact upon amateur athletes and regular exercisers

This body of research was selected for an independent Research Councils UK (RCUK) report that detailed the impact of academic research on sport and exercise practice published prior to the 2012 London Olympic games. This research was not funded by RCUK, and so being cited in this report shows clearly the significance of this research and the importance of the timing of publication prior to the London Olympic games.

Once we move away from elite sport it is far easier to "prove" the impact of the priming exercise research conducted at Aberystwyth University. We have provided clear examples of the wider dissemination of this research in which each states either the name of the author of the research, or specifically Aberystwyth University with the text of each source. In addition to widely available TV interviews (2.2), youtube clips (3.1), we provide specific evidence in cycling magazines (5), general fitness websites (6, 7) sports science websites (8, 9) and blogs (1, 10) that this impact is directly attributable to researchers at Aberystwyth University. Given the range of format and accessibility of these examples, it is argued that the reach of this body of research is significant.

5. Sources to corroborate the impact (indicative maximum of 10 references)

Primary reach – "Elite sport and practitioner/professional practice"

1. Dr Steve Ingham, Head of Physiology, English Institute of Sport
http://steveingham.blogspot.co.uk/2012/07/top-10-applications-no-3-prime-target.html

2. ITV4 interview with Gruffudd Lewis (Metaltek_KOO pro-cycling team)
   (2.1). Full uncut version of the interview
   (2.2). Edited broadcast version

3. Shane Stephens (Performance Coach Team Sky pro-cycling team)
   (3.1). http://www.youtube.com/watch?v=Q3VL5JCqQhQ&feature=youtu.be
   (3.2). Screenshot from video detailing the Team Sky "priming protocol"

4. Research Council UK report – "Supporting a UK success story: The impact of university research and sport development.
   http://www.rcuk.ac.uk/Publications/reports/Pages/success.aspx

Secondary reach: "Wider dissemination"

5. Cycling weekly article (readership number of 28,834; Jan-Dec 2012)

6. http://www.runnersworld.com/running-tips/prime-time

7. http://www.menshealth.co.uk/fitness/sports-training/running-truths-39671

8. http://sweatscience.com/the-priming-effect-how-a-hard-warm-up-can-help-performance/

9. http://www.pponline.co.uk/encyc/VO2-Kinetics-Oxygen-Kinetics-Exercise-performance-39310

10. http://blogs.menshealth.com/health-headlines/ultimate-warm-up-plan/2011/05/16