Institution: University of Kent

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

Title of case study: Enhancing Training and Performance in Elite Cycling

1. Summary of the impact

This impact case study describes the development and application of models of training and performance in elite cycling. These models have been used by elite medal winning teams in their search for competitive advantage in the UK (by British Cycling and British Triathlon, including the GB Olympic Cycling and British Triathlon Teams and the British Paralympic Team) and internationally (by the Australian Institute of Sport). These new cycling models have provided the basis for the development of new training processes that are influencing the way in which many nations prepare their elite riders. This work has contributed directly to enhance elite sports science practice in the field of cycling and the competitive advantage for British teams to which it contributes is envied around the world. The adoption of the underlying algorithms for the 'Wattbike' software has given our work a wider impact on sports practice and training methods, and it has been adapted for the 'Map My Tracks' website which is used by sports enthusiasts worldwide.

2. Underpinning research

Prof Louis Passfield joined the School of Sport and Exercise Sciences in 2007, creating its Endurance Research Group and leading its research in endurance training and performance. Passfield has more than 20 years' experience of applied work with Great Britain team cyclists and he continued to work for British Cycling alongside his work for the University of Kent. His research has been partly motivated by the insight and challenges presented through this collaboration. A core focus of the Endurance Research Group has been the training and performance of competitive cycling, and Passfield and colleagues have investigated these aspects from both a physiological and mathematical perspective.

Cycle Racing Model

The Cycle Racing Model, developed by Passfield at the University of Kent, is the first comprehensive mathematical model of both cycle and rider in the world. It represents a major development of all earlier work to provide a complete detailed mechanical model of cycling. Once at the University of Kent Passfield developed this detailed dynamic model using Matlab and Simulink, in collaboration with Dr Martin Bailey and Dr Helen Carter from the University of Brighton. This work formed the basis of Patrick Cangley's PhD thesis for which Passfield was one of the supervisory team. The new model builds on Passfield's previous modelling research that utilised a single static equation of motion to predict cycling performance. The new detailed model specifies separately aspects of every major mechanical component of the bicycle and rider. Pedal torque data is used to propel the model of bicycle and rider. Like a real bicycle the model can be balanced and steered around any race route or track that along with associated environmental conditions can be specified in detail. The model calculates the necessary bicycle and rider mechanics and corresponding cycling performance. The model has been validated successfully both theoretically and against field data (Cangley et al. 2011, 2012). Subsequently, this new model has been used (and is continuing to be used by British Cycling) to perform a range of "what if" scenarios for various aspects of cycling competition and training.

Cycle Training Model

In 2008, Passfield (PI) and Dr Simon Jobson both at the University of Kent used mathematical modelling to study the training process by analysing the power output data obtained directly from the bicycles of elite competitive cyclists. This project was funded by an EPRSC grant under the "UK Sports Achieving Gold" call, and involved collaboration with Prof Greg Atkinson and Dr Gabor Barton from Liverpool John Moores University and Prof Phil Scarf from the University of Salford. Their work resulted in the Sports Medicine review paper on the analysis and utilisation of training data (Jobson et al. 2009) and inspired subsequent work from the School's Endurance Research Group, such as Hopker et al. (2010).

The Cycle Training Model represents a new approach to investigating training because it reverses the normal method of scientific enquiry in this area by studying the training process, rather than its outcomes. This innovative approach has in turn enabled the Endurance Research Group to gain fresh perspectives and challenge accepted training practice. For example, with careful use of indirect calorimetry, our Endurance Research Group was able to demonstrate repeatedly that cycling efficiency changes with endurance training. Furthermore, using an elegant crossover design, Hopker et al. (2010) demonstrated that it is high-intensity training, not the widely-held moderate-intensity training, that is responsible for this change. Our laboratory was the first to demonstrate this finding that has changed widely adopted coaching principles.

Sprint Cycling Model

Further to the development of the Cycle Racing Model, in 2007 Passfield (as a Co-I with Prof Phil Scarf, University of Salford) was also successful in obtaining an EPSRC grant from the "Achieving Gold" scheme. This grant provided funding to examine the use of mathematical modelling to evaluate race tactics in track sprint cycling. The Sprint Cycling Model uses logistic regression to calculate the probability of race winning tactics. This analysis was derived from historical video footage from over 360 world-class sprint races. The model evaluates a range of different race scenarios and calculates the likelihood of success associated with them: for example, depending on the best and current speed of the cyclist, and the race distance remaining, the model will calculate the probability of winning associated with different race tactics such as whether to follow, where and when to overtake, which position on the track to ride, and so on. This work was embargoed before the London 2012 Olympics to gain a competitive advantage over rival nations and is therefore only now under peer review having been released for publication.

3. References to the research

Papers from the research underpinning the Case Study in chronological order (authors in bold were at the University of Kent at the time of the study)**:**

1. **Jobson SA**, **Passfield L**, Atkinson G, Barton G, Scarf P, The analysis and utilization of cycling training data. Sports Med. 2009; 39(10): 833-44.

   This paper was written as part of the EPSRC funded research programme. It identifies a number of methods by which training data can be modelled and their limitations.

2. **Hopker J**, Coleman D, **Passfield L**, Wiles J, The effect of training volume and intensity on competitive cyclists' efficiency. Appl Physiol Nutr Metab. 2010; 35(1): 17-22.

   This study demonstrates that cyclist's efficiency can be improved and that this occurs with supra-threshold training rather than moderate-intensity training.

3. **Hopker J**, Myers S, **Jobson SA, Bruce W, Passfield L**, Validity and reliability of the Wattbike cycle ergometer, Int J Sports Med. 2010; 31(10): 731-6.

   This was the first study to examine the validity and reliability of the Wattbike ergometer.

4. Cangley P, **Passfield L**, Carter H, Bailey M, The effect of variable gradients on pacing in cycling time-trials. Int J Sports Med. 2011; 32(2): 132-6.

   This is a field validation study of the mathematical model of cycling presented below.

5. Cangley P, **Passfield L**, Carter H, Bailey M, A model for performance enhancement in competitive cycling, Science and Motricite. 2012: 75:59-71.

   This paper presents a complete mechanical model of cycling developed in Matlab.

6. Moffatt JL, Scarf PA, **Passfield L**, McHale IG, and Zhang K, To lead or not to lead: analysis of the sprint in track cycling, Journal of Quantitative Analysis in Sports, (Submitted).

   Available at http://usir.salford.ac.uk/29554/

Grants supporting the research underpinning the Case Study:

- Scarf, McHale and **Passfield**. Optimum strategy in sport. Engineering and Physical Sciences Research Council (EPSRC). £68,816. 1/12/07 - 31/01/09.

- **Passfield, Jobson**, Atkinson, Barton and Scarf. Modelling training and performance in competitive cyclists. Engineering and Physical Sciences Research Council (EPSRC). £55,240. 17/10/07 - 16/08/08.

4. Details of the impact

Cycle Racing Model

The Cycle Racing Model is a comprehensive mathematical model of cycling and is the first in the world to include cycle and rider together. British Cycling and British Triathlon scientists used the model to formulate pacing strategies and inform equipment selection when Britain's elite athletes race on technically challenging courses. For example, the basis of this model was used to formulate the pacing strategies and race equipment selection for Britain's elite cyclists in the time-trial at the 2008 Beijing Olympics (at which Emma Pooley won a silver medal). The model was used to calculate specific scenarios of the impact on final race time of varying power output for different sections of major championship courses over the recent Olympic cycle.

In 2010 the Australian Institute of Sport (AIS) and in 2011 the British Paralympic Association both used this model to assist with the preparation of Australian cyclists and British Paralympic riders respectively. The AIS awarded Patrick Cangley (PhD student co-supervised by Passfield) a "Visiting Scholarship" to fund his travel to Australia and his accommodation whilst working with their scientists in Canberra. As this model provided a significant advance on their own previous (published) models the AIS scientists wanted to examine a number of what-if scenarios. The Cycle Racing Model enabled sport scientists at the AIS to explore many aspects of cycling performance and help their coaches and athletes in both track and road cycling disciplines. For example, joint torque was calculated with the model using inverse dynamics to better understand and inform specific Australian cycling team race and training practices. The British Paralympic Cycling team used the model to quantify the demands of the London 2012 Paralympic cycling course at Brands Hatch. This data was then used to fine tune the final preparation of British riders for this event and derive optimal race scenarios. The British Paralympic road cycling team won three gold, two silver and two bronze medals at the London Games. It is the exceptional mechanical detail of this model that has made it so valuable to scientists at the English Institute of Sport supporting British Cycling and British Triathlon's elite athletes. Indeed the model continues to be used to evaluate novel "what if" scenarios for various aspects of cycling competition and training and Passfield continues to use the model to assist British Cycling scientists with new novel applications of the model.

The Wattbike is a successful commercial cycle ergometer that is sold around the world. It is endorsed by British Cycling and used by them and Cycling Australia as part of their elite and talent development programmes. British Cycling uses the Wattbike to help identify talented cyclists for the future. The Cycle Racing Model was used to develop the algorithm incorporated into the Wattbike software to simulate a rider's cycling speed from the ergometer power output. This algorithm is fundamental to the use of the ergometer as it provides the basis of the distance and speed covered when riding on the ergometer. It also enables the rider to monitor performance over set distances and to race against another rider on a different ergometer.

Sprint Cycling Model

Scientists working with the British Cycling sprint team that included Olympic Champions Sir Chris Hoy and Victoria Pendleton CBE used the sprint cycling model to help devise the sprint race tactics of this team. In order to maintain a competitive advantage, publications from this work were embargoed until after the London 2012 Olympic Games and are only now being fully published.

Cycle Training Model

The Cycle Training Model was motivated by the need to better understand the wealth of data (e.g. power output, heart rate, cadence) that it is now possible to obtain from cyclists and their bicycles when training and racing. Several studies from the Endurance Research Group have led to a change in understanding training practices for elite endurance cyclists. For example, the findings of Hopker et al. (2010) informed this model which was used by Sir Bradley Wiggins in his preparation for his Tour de France and Olympic time trial victories in 2012.

Specifically, his science team identified the need to develop Wiggins' cycling efficiency as a key target and focus of his preparation. As described above, the findings from our laboratory have changed the way scientists and coaches think about efficiency and the training necessary to improve it. Indeed, a world leading sports scientist at the AIS has noted that this work provides a fresh perspective on important issues and that it has had a substantial impact on the way many nations prepare their elite cyclists (see sources to corroborate impact).

Wider impact

The cycle racing and training models are having impact far beyond professional cycling. Many people in gyms, health clubs and schools around the world use the Wattbike ergometer for exercise and training. Furthermore, aspects of the Cycle Training Model are being incorporated into the "Map My Tracks" website which has over 450,000 users worldwide. Map My Tracks provides GPS tracking on the web for people with GPS tracking embedded in their mobile phones or other GPS-enabled devices. The service is focused on sports enthusiasts who want to keep track of their running, cycling, kayaking, and other such pursuits. Map My Tracks is a product of Tinderhouse, a UK company based at the Innovation Centre, University Road, Canterbury.

5. Sources to corroborate the impact

Sprint Sports Scientist, English Institute of Sport

This letter from a senior sport scientist for the GB Cycling Team provides details of his use of the Sprint Cycling Model as part of the support he provided for the British Olympic Sprint team including riders Sir Chris Hoy and Victoria Pendleton CBE.

Sport Science Coordinator, Cycling Australia, and Senior Sport Scientist, AIS

This letter is from a world leading sports scientist at the Australian Institute of Sport (AIS) and Cycling Australia. It provides evidence of the worldwide impact of the cycling models developed by Passfield and colleagues, and confirms the models' direct influence on how AIS sport scientists advise and support Olympic and pre-elite cyclists. In 2010 the AIS flew Patrick Cangley (Passfield's PhD student) to Australia because the Cycle Racing Model was superior to their own models and helped them better understand the integrated demands of cycling. This world leading sports scientist comments that our cycling models have provided fresh perspectives and had a substantial impact on the way many nations prepare their elite cyclists, and that the competitive advantage given to GB teams by our research is a source of envy.

Head of Nutrition, British Cycling and Team Sky

This letter is from the Head of Nutrition and part of the infamous "marginal gains" team for both British Cycling and Team Sky. This letter states British Cycling and Team Sky used the Cycle Training Model to inform their successful preparation strategy for major races such as Bradley Wiggins's Tour de France victory and his London 2012 Olympic gold medal ride.

Sport Scientist, English Institute of Sport

This letter is from a sports scientist working at the English Institute of Sport in Loughborough. His work involves supporting British Cycling and British Triathlon's elite athletes. His letter provides examples of a range of uses the Cycle Training and Racing models have contributed to his work supporting British Cycling and Triathlon World and Olympic teams.

Cycling Coach, Great Britain Paralympic Team

This letter is from the Cycling Coach for the GB Paralympic Team. The letter details the GB Paralympic Cycling team's use of the Cycle Racing Model in preparation for the London 2012 Games.

Wattbike website (http://wattbike.com/uk/company)

This website provides factual evidence of Passfield's involvement in the development of the Wattbike ergometer. The site also details the worldwide impact of the Wattbike ergometer, that it is endorsed by British Cycling and used by a diverse range of institutions around the world including schools, gyms, British Cycling and the Australian Institute of Sport.