

Institution: University of Northumbria at Newcastle		
Unit of Assessment: 24 (Sport and Exercise Sciences, Leisure and Tourism)		
Title of case study: What it takes to win: establishing novel ways of training among Team GB cyclists to improve performance and enable Olympic success		
Period when the underpinning research was undertaken: 2012 – 2020		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s):	Role(s) (e.g. job title):	Period(s) employed by submitting HEI:
Kevin Thomas	Senior Lecturer / Associate Professor	15/11/2004 – present
Glyn Howatson	Professor	01/09/2009 – present
Stuart Goodall	Senior Lecturer / Associate Professor	01/02/2011 – present
Kirsty Hicks	Senior Lecturer	01/02/2016 – present
Period when the claimed impact occurred: August 2013 – December 2020		
Is this case study continued from a case study submitted in 2014? N		
1. Summary of the impact (indicative maximum 100 words)		
<p>Maintaining the world-class calibre of Team GB cyclists means that the training stress required to further improve performance is difficult to achieve and can lead to injury. Northumbria's research developed two innovative resistance-training methods that provide novel, safer ways to improve peak power output (PPO), the key determinant of sprint cycling performance. Adopted by GB Cycling ahead of Rio 2016, exemplars [text removed for publication] and [text removed for publication] applied the research in their physical preparation programme and improved their PPO [text removed for publication]. The use of these novel training methods contributed to medal success across multiple cycling events, helping to secure GBP25,980,427 of UK Sport's funding for the Tokyo Olympic cycle 2017 - 2021. GB Cycling continues to use Northumbria's training methods in its preparation for the Tokyo Olympics.</p>		
2. Underpinning research (indicative maximum 500 words)		
<p>After the London 2012 Olympics, sports science and sports medicine leaders identified a need to research novel, safer ways to improve cycling performance through maximising peak power output (PPO). It is well-known that the ability to generate high levels of PPO is directly correlated with cycling speed and consequently, interventions to affect PPO are highly valued. Typically, resistance training interventions have focused on heavy strength training exercises (e.g., back squats, deadlifts) to increase leg strength. However, Team GB cyclists are extremely strong, and thus these exercises require them to repeatedly handle very heavy loads (typically >2 times body mass) on a regular basis, which places huge stress on musculoskeletal structures, particularly the spine.</p> <p>Northumbria's <i>Optimising Human Performance</i> group led by Professor Glyn Howatson has a long-standing collaboration with the English Institute of Sport (EIS), formalised in a Memorandum of Understanding [E1], to support collaborative working to deliver new knowledge to the elite sport arena. The EIS's mission is to advance sports science and practice to ensure Great Britain's Olympic and Paralympic success. Northumbria researchers (Goodall, Hicks, Howatson and Thomas) led two projects (between 2013 and 2019) in conjunction with EIS and GB cycling practitioners (including Barratt, Leeder, [text removed for publication] and Evans). In these projects, Northumbria doctoral students (Kordi and Harden) were embedded within GB cycling as practitioner-researchers, working directly with Team GB coaches and athletes to</p>		

specifically research novel resistance training methods aimed at maximising PPO and leg strength. Publication of the outcomes of this research was embargoed until after the 2016 Rio Olympics to protect Team GB's competitive advantage.

The Northumbria-led work established the key determinants of PPO in elite cyclists and subsequently studied how two novel resistance-training methods could improve PPO 1) cycling-specific isometric training that allowed maximum strength expression at fixed muscle lengths in sport-specific body positions; and 2) supramaximal eccentric training using a novel leg press device that exploited the capacity of eccentric (or lengthening) muscle actions to produce higher levels of strength than traditional concentric (or shortening) muscle actions.

The team first investigated the physiological determinants of PPO in an elite cycling group, including current World Record holders [R1, R2]. This study identified a strong association between isometric strength of the knee extensors and cycling PPO. A subsequent 'proof of concept' case study successfully implemented a cycling-specific isometric strength training protocol in an elite cyclist's programme, improving PPO by 6% [E2]. This cycling-specific isometric strength training protocol was subsequently tested in a controlled trial, where the training regime successfully increased PPO in a group of Team GB cyclists (n = 13) by 4%; a major improvement in already elite athletes [R3].

The second research project investigated the efficacy of a custom-built 45° incline leg press device (produced by Sportesse, Somerset, UK) that offers an eccentric overload training stimulus [R4, R5]. The research established a range of optimal parameters to implement supramaximal eccentric leg strength training. In a randomised-control trial that included elite track cyclists, the training regime was compared with traditional loading, showing that supramaximal eccentric leg press exercise was effective in improving indices of leg muscle strength [R6]. Both training methods developed by Northumbria were adopted by the EIS.

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

- R1.** Kordi, M., Folland, J., **Stuart Goodall**, Haralabidis, N., Madden-Wilkinson, T., Patel, T., Leeder, J., Barratt, P., and **Glyn Howatson (2020)** 'Mechanical and morphological determinants of peak power output in elite cyclists' *Scandinavian Journal of Medicine and Science in Sports* **30**(2): 227-237 <https://doi.org/10.1111/sms.13570>
- R2.** Kordi, M., **Stuart Goodall**, Barratt, P., Rowley, N., Leeder, J., and **Glyn Howatson (2017)** 'Relation between peak power output in sprint cycling and maximum voluntary isometric torque production' *Journal of Electromyography and Kinesiology* **35**: 95-99 <https://doi.org/10.1016/j.jelekin.2017.06.003>
- R3.** Kordi, M., Folland, J., **Stuart Goodall**, Menzies, C., Patel, T., Evans, M., **Kevin Thomas**, and **Glyn Howatson (2020)** 'Cycling-specific isometric resistance training improves peak power output in elite cyclists' *Scandinavian Journal of Medicine and Science in Sports* <https://doi.org/10.1111/sms.13742>
- R4.** Harden, M., Wolf, A., Russell, M., **Kirsty Hicks**, French, D., and **Glyn Howatson (2018)** 'An evaluation of supramaximally loaded eccentric leg press exercises' *Journal of Strength and Conditioning Research* **32**(10): 2708-2714 <https://doi.org/10.1519/JSC.0000000000002497>
- R5.** Harden, M., Wolf, A., Haff, G., **Kirsty Hicks**, and **Glyn Howatson (2019)** 'Repeatability and specificity of eccentric force output and the implications for eccentric training load prescription' *Journal of Strength and Conditioning Research* **33**(3): 676-683 <https://doi.org/10.1519/JSC.0000000000002965>
- R6.** Harden, M., Wolf, A., Evans, M., **Kirsty Hicks**, **Kevin Thomas**, and **Glyn Howatson (2020)** 'Four weeks of augmented eccentric loading using a novel leg press device improved leg

strength in well-trained athletes and professional sprint track cyclists' *PLoS ONE* 15(7): e0236663 <https://doi.org/10.1371/journal.pone.0236663>

EIS funded practitioner-researchers: M. Kordi, EIS practitioner, and EIS fee-paid, part-time doctoral student at Northumbria (2013-2019). M. Harden, EIS practitioner, and EIS-funded doctoral studentship (GBP84,704) at Northumbria (2015-2019).

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

4.1 Novel training methods

The EIS is the principal UK organisation supporting British athletes competing at the Olympic and Paralympic Games. Through collaboration with the EIS [E1], Northumbria's researchers designed and validated new cycling-specific isometric and eccentric training regimes that are more effective than traditional resistance training [E2-E4]. Team GB cyclists are considered amongst the best in the world in their respective events and have extremely well-developed physical qualities. Consequently, the training stress required to evoke further adaptation is challenging to achieve. The training methods developed by Northumbria have been successfully implemented by the EIS [E2, E3] to provide new, safer ways to improve PPO, and have improved the cycling performance of Team GB athletes [E2, E4]. For example, a case study with an elite track-cyclist reported a 6% improvement in PPO after a period of cycling-specific isometric training: [text removed for publication].

4.2 Improved performance

[text removed for publication] during the 2012-2016 Olympic cycle, explained the impact of Northumbria's work in the build-up to Rio 2016: '*By including specific eccentric training in the riders' preparation, we have seen an average improvement in peak power output of [text removed for publication] across the sprint track team riders. [text removed for publication] (multiple World and Olympic medallist) used a 4-week block of eccentric resistance training prior to competing. [text removed for publication] maximum strength increased by 8-10% (equating to about 2.5 times body mass) and [text removed for publication] cycling peak power output increased by approximately [text removed for publication] during this period and [text removed for publication] subsequently went on to win [text removed for publication] medals in Rio' [E3].*

[text removed for publication] stated '*Cycling specific resistance training has been implemented across Podium, Elite, and Paralympic programmes... We have seen an average improvement in peak power output of [text removed for publication]... Over 30 riders across our Olympic and Paralympic programmes [>50% of the cohort] have employed this strength training stimulus as part of their regular schedule' [E4].*

4.3 Reduction in injury risk

Integration of the novel training programmes also enabled athletes with compromising injuries to increase leg strength, which Northumbria has shown to be a critical determinant of cycling performance [R1]. Traditional resistance training methods used to improve PPO necessitate very heavy loading in exercises such as the back squat and deadlift; this training stimulus carries risks for elite cyclists, primarily because of concerns over injuries to spinal structures. The new training methods specifically developed by Northumbria were applied by Team GB cyclists to develop leg strength. These training methods carried less risk of injury than the traditional heavy barbell strength training, reducing injury risk for athletes.

For example, the significant benefits of this novel training programme were realised by Rio 2016 Olympic [text removed for publication] medallist, [text removed for publication]. [text removed for publication] stated '*Prior to this research I was unable to fully maximise my resistance training program as I have ongoing musculoskeletal complications that mean I can't tolerate traditional resistance training. The research conducted with Mehdi Kordi and Northumbria University identified a novel training technique that has allowed me to train to a level where I was able to qualify for the 2016 Rio Olympics and win [text removed for publication]' [E5].*

4.4 Olympic success during Rio 2016

Through supporting EIS practitioners and athletes in their pursuit of innovation, Northumbria research findings contributed to Team GB's performance success at the Rio 2016 Olympics. Embedding these research-informed novel training techniques in preparation for Rio 2016 enabled Team GB Cycling to improve their athletes' performance and increase their capacity for medal success. [text removed for publication] stated '*Ultimately, the goal of our organisation is to win Olympic medals, and the primary impact of Professor Howatson and Mehdi's work is to successfully increase our medal-winning potential... Given that the physical preparation of athletes is a primary determinant of success in cycling, the improvements in the training process made as a consequence of Northumbria's research undoubtedly increased our potential to win medals across multiple events. The impact is ongoing as we prepare for Tokyo 2020, where [their findings] continue to inform our training strategy*' [E4].

[text removed for publication] said '*It is without doubt that the [cycling-specific] isometric training intervention played a significant part in my medal successes at the Rio Olympics; my cycling peak power output increased. This modality of training has also been adopted by my peers*' [E5].

4.5 Success breeds success: economic impact of Team GB success at the Olympics

UK Sport inspires the nation through Olympic and Paralympic medal success. GB Cycling performance, and victories by athletes [text removed for publication] during Rio 2016, ensured the continuation of the team's funding into the new Tokyo 2020 Olympic cycle (2017 – 2021). GB Cycling was allocated GBP25,980,427 by UK Sport [E6, p18], remaining among the five most funded sports in Team GB. This investment was made in a climate of significant affordability challenges, where for the first time five sports that underperformed during Rio 2016 were not funded by UK Sport [E6, p6, 13-14]. This meritocratic approach to funding allocation demonstrates how important it is to continuously improve training practices with athletes. By collaborating with EIS and Team GB, Northumbria developed innovative resistance training methods which made significant contributions to Rio 2016 performance success and have been adopted as part of preparations in elite cycling for the delayed Tokyo Olympics.

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

Ref.	Source of corroboration	Link to claimed impact
E1	Memorandum of Understanding with English Institute of Sport (EIS)	Testifying to Northumbria's long-standing and applied collaboration with the EIS
E2	Published case study: Kordi, M., Evans, M., and Glyn Howatson (2020) 'Quasi-isometric cycling: a case study investigation of a novel method to augment peak power output in sprint cycling' International Journal of Sports Physiology and Performance DOI: https://doi.org/10.1123/ijsp.2020-0100	Testifying improvement in performance and PPO among athletes after isometric training
E3	Testimonial - [text removed for publication]	[text removed for publication]
E4	Testimonial - [text removed for publication]	[text removed for publication]
E5	Testimonial - [text removed for publication]	[text removed for publication]

Impact case study (REF3)

E6	Compilation of four UK Sport documents (Board Minutes from September 2016, Board Minutes from December 2016, Sport Investment for Tokyo 2020 Cycle, Press Release about the funding)	Collectively, these documents corroborate that GB Cycling received support of GBP25,980,427 for the 2017 – 2021 Olympic cycle from UK Sport directly related to Rio 2016 medal success. This investment was made in the climate of overall funding cuts with five other sports deprived of funding. Documents stress meritocratic approach in funding allocation
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