

Institution: Loughborough University		
Unit of Assessment: C24 Sport and Exercise Sciences, Leisure and Tourism		
Title of case study: Faster, healthier, longer: Increasing pace, reducing injuries, and extending the playing careers of cricket fast bowlers		
Period when the underpinning research was undertaken: 2005 - present		
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:
Prof. Mark King	Professor of Sports Biomechanics	1999 – present
Prof. Fred Yeadon	Professor of Computer Simulation in Sport	1990 – 2016
Dr Katherine Brooke-Wavell	Senior Lecturer in Human Biology	1998 – present
Dr Paul Felton	Research Associate	2015 – 2019
Period when the claimed impact occurred: January 2014 – 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>Fast bowling places enormous loads and stresses on a bowler's body, and the repetitive nature along with the continual aspirations for increased pace can be severely career-limiting. The fast bowling research programme at Loughborough University has developed and applied cutting-edge biomechanical analysis and individualized computer modelling to guide bespoke technical changes which have led to the following impacts: 1) improved performance; 2) enhanced careers by remediating injuries and extending international service; 3) augmented coach education policy and thereby improved fast bowler development; and 4) improved injury prevention and changed workload policy published in revised national fast bowling guidelines. As a result, every England and Wales Cricket Board (ECB, national governing body for cricket) elite fast bowler and top-level fast bowling coach has benefitted from the programme.</p>		
2. Underpinning research (indicative maximum 500 words)		
<p>The desire to help pace bowlers bowl faster without suffering injury has been behind the long-standing collaboration between the ECB and Professor King's cricket research group at Loughborough University. The group's early research into the biomechanics of elite fast bowling, funded by the ECB, established that four technique variables were fundamental to bowling fast [R1] and explored the influence of lower trunk posture, front-leg motion and forces through the body during ball delivery [R2]. This provided a clear understanding of the underlying link between technique, performance, and the likelihood of injury to fast bowlers. Early in the collaboration a new peer reviewed method was developed to quantify elbow extension and hyperextension during a delivery and used to demonstrate that the bowling action of England Women's fast bowler, Jenny Gunn, was legal [R3].</p> <p>To understand the factors limiting an <i>individual</i> bowler's performance, in 2010 the ECB funded further research which adopted a theoretical approach to investigate optimum performance. A cutting-edge, bowler-specific, forward-dynamics simulation model of the front-foot contact phase of the fast bowling delivery stride was developed, to investigate how different factors (e.g. technique or strength) affected the performance of an elite fast bowler [R4]. For the</p>		

specific bowler modelled, the simulation analyses found that the front leg should be kept straighter, the amount of trunk flexion should be increased and the bowling arm should be delayed, leading to a potential improvement in ball speed of 10% for this individual [R4]. The technical changes used by the simulation model to improve bowling speed were consistent with those that had been found to be related to increased ball speed in the previous experimental research [R1], further validating the approach of using individualized computer models. Following coaching based on these findings, this bowler exceeded the predicted speed increase.

In 2016 the ECB and Loughborough University funded a new research project to investigate the risk factors for lumbar stress fractures in fast bowlers because these fractures are the most prevalent category of injury in cricket and lead to the greatest time-loss from the game. A programme of systematic elite fast bowler testing and monitoring was devised and implemented which revealed that bowling more than 39 overs in a week tripled the likelihood of a subsequent lumbar stress fracture and explained 66% of all lumbar stress fractures [R5]. Further research found that the lumbar spine of fast bowlers is uniquely adapted, demonstrating extremely high bone mineral density in the third and fourth lumbar vertebra, which is likely to protect against stress fractures [R6].

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

- R1** Worthington, P.W., King, M.A., Ranson, C.A. (2013). Relationships between fast bowling technique and ball release speed in cricket. *Journal of Applied Biomechanics*, 29, 78-84. <https://doi.org/10.1123/jab.29.1.78>.
- R2** Ranson, C.A., Burnett, A.F., King, M., Patel, N., O'Sullivan, P.B. (2008). The relationship between bowling action classification and three-dimensional lower trunk motion in fast bowlers in cricket. *Journal of Sports Sciences*, 26, 267-276. <https://doi.org/10.1080/02640410701501671>.
- R3** King, M.A., Yeadon, M.R. (2012). Quantifying elbow extension and elbow hyperextension in cricket bowling: A case study of Jenny Gunn. *Journal of Sports Sciences*, 30, 937-947. <https://doi.org/10.1080/02640414.2012.682082>.
- R4** Felton, P.J., Yeadon, M.R., King, M.A. (2020). Optimising the front foot contact phase of the cricket fast bowling action. *Journal of Sports Sciences*, 38, 2054-2062. <https://doi.org/10.1080/02640414.2020.1770407>.
- R5** Alway, P., Brooke-Wavell, K., Langley, B., King, M., Peirce, N. (2019). Incidence and prevalence of lumbar stress fracture in English County Cricket fast bowlers, association with bowling workload and seasonal variation. *BMJ Open Sport & Exercise Medicine*, 5, e000529. <http://dx.doi.org/10.1136/bmjsem-2019-000529>.
- R6** Alway, P., Peirce, N., King, M.A., Jardine, R., Brooke-Wavell, K. (2019). Lumbar bone mineral asymmetry in elite cricket fast bowlers. *Bone*, 127, 537-543. <https://doi.org/10.1016/j.bone.2019.07.030>.

Evidence of the quality of the research

These papers have been peer-reviewed and published in international scientific journals. In addition, Dr Felton's individualized application of computer simulation received the prestigious New Investigators Award at the 35th International Symposium on Biomechanics in Sports, Cologne, Germany, 2017.

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

The impacts from the programme of ECB funded research investigating the link between technique, performance and injury in cricket fast bowling have been possible because of the strong relationships developed between Loughborough University and the ECB, with exceptional cooperation and "buy-in" from players and coaches: "We have amazing experts around us in the sports science team at Loughborough, who have been brilliant for the England fast bowlers", (ECB Lead Fast bowling Coach, Kevin Shine, 2019 [S1]).

These relationship pathways have led to the following impacts:

1) Improved performance

The exceptional feature of Loughborough University's research on individualized coaching has been the development, evaluation and optimization of fast bowling using a computer simulation model funded by the ECB [R1, R2, R4]. The initial simulation findings corroborated the experimental research, but personalizing the model enabled player-specific coaching interventions to be derived [S2, S3, S4]. Over 100 elite fast bowlers have undergone biomechanical analysis at Loughborough [S2, S9], including 76% of England fast bowlers selected since 2014, with each bowler and their respective bowling coach receiving advice based on the latest research in the form of a pace matrix [S3, S4]. The ECB lead fast bowling coach [S3], ECB Chief Medical Officer [S9], and the ECB Head of Science and Medicine [S4] are clear that the research carried out has improved bowling performance.

In 2015 the 'Technical Excellence Project' [S3] was introduced which further developed and embedded the process of analysis and individualized interventions within the ECB Pace Programme (a tailored training camp for potential elite fast bowlers with input from the National Leads for Fast Bowling, Strength and Conditioning, Nutrition and Physiotherapy) [S1, S4, S5]. For example, in the 2017 off-season (12 weeks), all members of the ECB Pace Programme had bespoke simulation models [S2] and player-specific coaching recommendations produced for the 2018 pre-season [S3].

For example, Sam Curran progressed through the ECB Pace Programme to debut for England in Test and One Day International cricket in June 2018 and was awarded 'Player of the Series' in his first full test series, against India (then ranked number one in the world). He has subsequently secured franchise contracts in T-20 cricket around the world which total in excess of \$1 million.

The importance of the biomechanics research programme at Loughborough has led to the ECB developing an online platform for storing and accessing a player's coaching history (Interactive Coach) [S2, S3, S5]. This enables technical and coaching recommendations based on the research in the form of a pace matrix to be used by players and coaches, and for coaches to feed back to the team at Loughborough [S3].

2) Enhanced careers of international bowlers

In addition to improved bowling performance, the biomechanics research has led to career-saving biomechanical interventions [S4]. The most high-profile beneficiaries in the England men's game have been Mark Wood (Cricket World Cup winner, 2019), Stuart Broad MBE (514 test wickets) and James Anderson OBE (world leading wicket taker among fast bowlers in test cricket with 600 wickets) [S1, S6].

"I'm very reliant on the information that comes through Loughborough not just crunching numbers for the sake of it; we are actually trying to become better cricketers" James Anderson OBE, 2019 [S6].

In the England women's game, biomechanical analysis of Jenny Gunn MBE's bowling action proved that her unusual bowling action was legal [R3], enabling her to go on to bowl at the 2009 Women's World Cup and then to continue playing to become five times women's Ashes winner and triple World Cup winner before her retirement in October 2019 [S7].

3) Augmented coach education policy

The knowledge gained through biomechanical analysis and individualized computer modelling has fed through to coach education and practice, impacting all high-level coaches (via ECB coaches conferences, coach education courses and the various ECB media outlets) [S8]. In

2018, the ECB rebranded their Level 4 coach award as the 'Specialist Coach' programme, with the Pace Bowling specialist skills module built upon Loughborough University's research, and candidates actively engaging with biomechanical analysis as part of their learning and assessment [S3, S8]. As reported by former ECB Lead Fast Bowling Coach Kevin Shine:

"Most counties now have a fast bowling coach, and they've pretty much all come through the ECB Level 4 programme, which is absolutely world-leading in coach education" [S1].

Through the integration of the research into coach education, even bowlers not analysed as part of the elite programme have benefitted from the coaching insights provided [S8].

4) Improved injury prevention and changed workload policy

The results of the ECB funded research on monitoring workload and injury [R5, R6] led to the ECB's decision to change the national fast bowling workload policy [S9]. New national bowling workload guidelines for 18- to 24-year-old fast bowlers throughout England and Wales were introduced for the 2020 season to prevent lumbar stress fractures and enhance lumbar spine bone adaptation [S9, S10]. Knowledge regarding inactivity driven bone loss, gained as part of this research, [R6] resulted in an 8-week "return to bowling" programme implemented by the ECB (and subsequently also adopted by the International Cricket Council) [S9] as a response to the disruption and delay caused by Covid-19 restrictions in 2020. No incidence of lumbar stress fracture was reported in England and Wales this season compared to the average incidence of eight [S9]. ECB coach education and medical CPD days now include a session focused on optimizing lumbar spine bone adaptation in young fast bowlers which incorporates workload, biomechanics, nutrition, strength and conditioning, and lifestyle factors [S9].

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

source	details	impact
S1	England and Wales Cricket Board; Kevin Shine to leave ECB (1 st Nov. 2019). https://www.ecb.co.uk/news/1476822/kevin-shine-to-leave-ecb .	performance, careers, coach education policy
S2	The Cricketer magazine article (20 th February 2018) – Pacemakers: How the ECB's Loughborough sports scientists are promoting speed among their bowlers http://www.thecricketer.com/Topics/features/pacemakers-how-the-ecb's-loughborough-sports-scientists-are-promoting-speed-among-their-bowlers.html	performance
S3	Kevin Shine, ECB Lead Fast Bowling Coach 2006 – 2019. Letter of support.	performance, careers, coach education policy
S4	Raph Brandon, ECB Head of Science and Medicine 2014 – 2020. Letter of support.	performance, careers, injury prevention and workload, coach education policy
S5	The Times article (11 th January 2018) – How England are creating their own Mitchell Starc https://www.thetimes.co.uk/article/how-england-are-trying-to-create-their-own-mitchell-starc-8rbppnw6w	performance, careers
S6	BBC Radio 4 programme – Build me a fast bowler: https://www.bbc.co.uk/sounds/play/m0005dyn	performance, careers
S7	The Cricketer (1 st July 2019) – "I would have wanted to stop bowling - I didn't really enjoy it" Jenny Gunn article.	careers

	https://www.thecricketer.com/Topics/news/jenny_gunn_womens_ashes_england_australia_i_would_have_wanted_to_stop_bowling_i_didn't_really_enjoy_it.html?platform=hootsuite	
S8	John Neal, ECB Lead for Coach Education. Letter of support.	coach education policy
S9	Nick Peirce, ECB Chief Medical Officer. Letter of support.	performance, injury prevention and workload
S10	ECB Coach Development (2020) – Professional Game: Coaches' guidance for competitive and safe cricket	injury prevention and workload