Institution: St Mary's University, Twickenham

Unit of Assessment: 24, Sport and Exercise Sciences, Leisure and Tourism

Title of case study: Application of methods to reduce risk of injury in elite performance environments and aid rehabilitation in sport and clinical settings

Period when the underpinning research was undertaken: 2016-2020

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:
1. Dr Stephen Patterson 2. Dr Jamie Tallent 3. Dr Luke Hughes 4. Mr Matt Springham 5. Dr Charles Pedlar 6. Prof Conor Gissane 7. Mr Joseph Shaw 8. Mr Adam Mattiussi	1. Associate Professor in Exercise Physiology 2. Senior Lecturer in Strength & Conditioning 3. PhD student; Post-doctoral researcher 4. Senior Lecturer in Strength & Conditioning 5. Associate Professor in Sport Physiology 6. Professor in Biostatistics and Research 7. PhD student 8. S&C Coach and PhD student	1.1/09/2009-present 2.1/05/2017-present 3.2015-2018 (PhD student); 01/02/2019-present (Post-doc) 4.08/02/2017-present 5.01/09/2009-present 6.03/09/2001-31/08/2018 7.01/02/2019-present 8.01/08/2016-present (S&C Coach); 01/10/2019-present (PhD student)

Period when the claimed impact occurred: 2017-2020

Is this case study continued from a case study submitted in 2014? N

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

Our research has realised significant and wide-reaching impact in the application of methods to both reduce risk of injury in sport and performance contexts and aid rehabilitation when injuries occur.

Application of Blood Flow Restriction Training for Rehabilitation from Injury in Sport and Clinical Settings

Research examining the application of Blood Flow Restriction Training (BFR) has informed development of organisational policy at national level by the English Institute of Sport (EIS) and assisted with the development of guidelines for the application of this technique by governing bodies such as the Football Association (FA), Rugby Football Union (RFU), Lawn Tennis Association (LTA), professional sports teams (e.g., Sport Lisboa e Benfica), sports medicine hospitals (e.g., Aspetar), and international professional associations (e.g., American Physical Therapy Association).

Our research has also informed the application of rehabilitation techniques by global medical training companies for their clinical rehabilitation programmes in the USA with the Department of Defense (DOD) and the National Aeronautics and Space Administration (NASA).

Monitoring Workload to Reduce Injury Risk

The England and Wales Cricket Board (ECB) and Royal Ballet Company both now employ methods to quantify and monitor workload to identify where there are increased levels of injury risk. In parallel, the ECB have seen reduced injury rates on international tours, whilst the Royal Ballet Company have altered rehearsal and performance schedules to reduce the risk of injury and manage the workload of dancers.

2. Underpinning research (indicative maximum 500 words)

The aim of the research in this impact case study was to develop evidence that could be applied to reduce injury risk and optimise performance, as well as providing an evidence-base to enhance the application of blood flow restriction training as a rehabilitation technique where serious injuries occur.

Application of Blood Flow Restriction Training for Rehabilitation from Injury

Where injuries occur that require the athlete or performer to cease engagement in the activity, Blood Flow Restriction (BFR) training is a rehabilitation technique which allows injured persons to regain strength and muscle mass whilst using light loads, which is often essential during rehabilitation from serious injury, since heavy loads cannot be tolerated. To investigate the level of understanding in the application of BFR training, data was collected from 250 clinicians and sport medicine practitioners around the world. It revealed that although BFR training was popular and widely practised, the level of understanding and method of application was inconsistent with published evidence (**3.1**). Subsequent experimental work has tested aspects of BFR training to inform its application. Using a randomised, crossover, counterbalanced design our research has demonstrated differences between BFR systems in the pressure they apply and, by recording perceptions of pain and exertion alongside the pressure applied by each system, our researchers were able to recommend that BFR cuffs which automatically adjust pressure during exercise are the most beneficial and safest for use in BFR training programmes (**3.2**). Further experimental research has provided evidence for the effectiveness of BFR as a tolerable and effective rehabilitation technique both in sporting and non-sporting groups. A randomised control trial in collaboration with University College London Hospitals NHS Foundation Trust found those undergoing anterior cruciate ligament reconstruction who received an eight-week BFR training intervention alongside standard prescribed rehabilitation methods demonstrated improved physical and functional outcomes whilst also reporting a reduction in pain compared to those receiving standard rehabilitation programmes only (**3.3**).

Reducing Risk of Injury

The importance of managing injury risk was illustrated by Tallent, who recorded injury data from 47 international cricketers over 32 months and showed the association between a team's injury status and the outcome of international cricket matches and series. When less affected by injury the team were more likely to be successful (**3.4**). To reduce risk of injury through excessive workload, a non-invasive measure of workload was devised using individualised workload totals. Using this method, acute and chronic workload, along with measures of wellness, injury, and illness status, were recorded for five international tours over three years. Although extended periods of high workload were associated with injury risk, high acute workloads- especially rapid increases in acute workload- were most strongly associated with increased risk of injury (**3.5**). In a professional ballet company, workload monitoring has shown that professional dancers may perform 145 shows of 15 different productions across a season. Consequently, a measure of internal training load in professional classical ballet dancers has been developed and validated, which is valuable for effective periodisation of rehearsal schedules (**3.6**).

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

3.1. Patterson S. D., & Brandner, C. (2018). The role of blood flow restriction training for applied practitioners: A questionnaire-based survey. *Journal of Sports Sciences*, *36*, 123-130. https://doi.org/10.1080/02640414.2017.1284341

3.2. Hughes, L., Rosenblatt, B., **Gissane, C**., Paton, B., & **Patterson, S. D.** (2018). Interface pressure, perceptual, and mean arterial pressure responses to different blood flow restriction systems. *Scandinavian Journal of Medicine and Science in Sports*, *28*, 1757-1765. https://doi.org/10.1111/sms.13092

3.3. Hughes, L., Rosenblatt, B., Haddad, F., **Gissane, C.**, McCarthy, D., Clarke, T., Ferris, G., Dawes, J., Paton, B., & **Patterson, S. D.** (2019). Comparing the effectiveness of blood flow restriction and traditional heavy load resistance training in the post-surgery rehabilitation of anterior cruciate ligament reconstruction patients: a UK National Health Service

randomised controlled trial. *Sports Medicine*, *49*, 1787-1805. https://doi.org/10.1007/s40279-019-01137-2
3.4. Tallent, J., de Weymarn, C., Ahmun, R., & Jones, T. W. (2020). The impact of all-rounders and team injury status on match and series success in international cricket. *Journal of Sports Sciences*. https://doi.org/10.1080/02640414.2020.1798721
3.5. Ahmun, R., McCaig, S., **Tallent, J.,** Williams, S., & Gabbett, T. (2019). Association of daily workload and wellness, injury and illness during competitive tours in international age group cricket. *International Sports Physiology and Performance*, *14*, 369-377. https://doi.org/10.1123/ijspp.2018-0315
3.6. Shaw, J. W., **Springham, M**., Brown, D. D., **Mattiussi, A. M**., **Pedlar, C. R.**, & **Tallent, J**. (2020). The validity of the session rating of perceived exertion method for measuring internal training load in professional classical ballet dancers. *Frontiers in Physiology*, https://doi.org/10.3389/fphys.2020.00480

Research Grants and Research Funding
1. Dr Stephen Patterson. Post-doctoral research funding into blood flow restriction training. Delfi Medical, Canada. 2019-2021. £92,000.
2. Dr Stephen Patterson. In-kind equipment donation. Delfi Medical, Canada. 2018-2020. £30,000.
3. Dr Stephen Patterson. In-kind equipment donation. Delfi Medical, Canada. 2016-2018. £11,000.
4. Dr Charles Pedlar, Dr Jamie Tallent, Mr Matt Springham. Workload and injury monitoring in professional dance. Royal Ballet Company. 2018-2021. £412,000.
5. Dr Chris Steer, Dr Charles Pedlar. Ballet movement detection feasibility for overuse injury modelling within Royal Ballet School training programmes. Models to Decisions (M2DER006). 2018-2019. £6,000.

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

Application of Blood Flow Restriction Training for Rehabilitation from Injury
Based on our research showing that application of BFR training was inconsistent and often misaligned with research evidence (3.1), organisations have seen the importance of policy to guide its use. The English Institute of Sport (EIS), which is the largest single provider of science, medicine, technology, and engineering services within the sport sector to Olympic and Paralympic sports in the UK, have collaborated with Patterson and Hughes to write their first ever policy on BFR training (**5.1**). The policy ensures that all EIS clinical practitioners, across each of its nine sites, are using the same guidelines, and has helped the organisation realise a higher quality and more consistent application of BFR training. The EIS has benefitted by enhancing its risk screening processes and use of methods to determine limb occlusion and training pressures (**5.1**). Practitioners at the EIS now individualise all limb occlusion pressures, in the position of the chosen exercise, and have revised their screening processes based on recommendations from our research (3.1, 3.2) (**5.1**).

Based on his empirical findings concerning the use of BFR training, Patterson brought together researchers from around the world to write the world's first set of guidelines that outlined recommendations for methodology, application and safety when using BFR training. National governing bodies, including the Football Association (FA), Rugby Football Union (RFU), and Lawn Tennis Association (LTA), have used our empirical research findings outlined in Sections 2 and 3 as well as Patterson's collective guidelines to inform their application of BFR training. The RFU invited Patterson to present at a performance services meeting in 2015 to advise on how BFR training could be implemented within the structures of England Rugby and, more recently, Hughes delivered an invited presentation to advise on the application of BFR training in the Rugby 7s set-up. England men's and women's Rugby 7s now implement BFR training in rehabilitation programmes for *all* injured players to recover muscle and strength losses. The research informs practice to reduce pain (3.3), to select the appropriate cuff pressures (3.2), and to inform the choice and schedule of exercises (3.3), with all aspects underpinned by Patterson's collective guidelines for the

application of BFR training (**5.2**). Similarly, the FA now incorporate BFR into rehabilitation programmes for all players recovering from injury. Using our research, the FA's rehabilitation team at St George's Park have a greater understanding of how to best apply BFR and have particularly benefitted from research on implementing BFR training with those suffering ACL injuries (3.3) (**5.2**). The LTA also now employ BFR training as part of their therapy, rehabilitation, and strength and conditioning services to British tennis players, with their guidelines also informed by Patterson's research findings and recommendations (**5.2**).

Our research has also informed practice at professional sports teams. Patterson delivered an invited workshop on BFR training to Sporting Lisboa Benfica, following which their Human Performance Department incorporated BFR training in its rehabilitation strategy for injured players. Practitioners at the club use Patterson's recommended guidelines to direct the application of BFR training, with research in populations suffering ACL injury (3.3) being especially informative (**5.3**). The Aspetar Orthopaedic and Sports Medicine Hospital, Doha, Qatar, has also benefitted particularly from our research on applying BFR for rehabilitation post-ACL surgery. The hospital is the largest in the Middle East, providing inpatient and outpatient care to all registered and professional athletes in the country, and it conducts over 400 ACL surgeries each year. Their rehabilitation pathway for those undergoing these surgeries now incorporates BFR training that is informed by Patterson's research and guidelines (3.3) (**5.4**).

The American Physical Therapy Association (APTA) represents over 100,000 physical therapists and seeks to improve health and quality of life through the application of education and research. Using Patterson's research findings and associated recommendations, APTA have adopted the use of BFR training in their scope of practice for the first time in their 99-year history. All APTA members who include BFR training in their practice are directed to guidelines on its use written by Patterson (**5.5**).

The impact of our research on BFR training has translated beyond sport. Owens Recovery Science Inc. is a company specialising in BFR training in clinical settings. They have used Patterson's research evidence and guidelines on BFR use to form the core of their global medical training programme, which is used by their 5,378 trained medical providers around the world who perform an estimated 3.5 million BFR training sessions annually. Recommendations from Patterson's research form the foundation of training programmes offered by Owens Recovery Science, which are delivered to some of the largest healthcare systems in the USA and provide clinical rehabilitation to NASA, the USA Olympic Team, and sports teams across the National Basketball Association (NBA), National Football League (NFL), National Hockey League (NHL), and Major League Soccer (MLS). BFR training, informed by Patterson's research, is now on workers' compensation in every professional sports league in the USA. Owens Recovery Science have also used Patterson's research (3.1, 3.2, 3.3) to inform their use of BFR training to aid recovery from lower limb trauma in military personnel and cite the research as having a major impact on the way lower limb trauma is treated. The lower limb was the most injured body region of US soldiers during conflicts in Afghanistan and Iraq, and Owens Recovery Science have used Patterson's research on BFR training to restore calf strength and lower limb blood flow to make crucial advances in their limb salvage programme. BFR training, using Patterson's guidelines is now used throughout the Department of Defense (DOD) and includes every major military treatment facility and Special Operations base (**5.6**).

Monitoring Workload to Reduce Injury Risk and Optimise Performance

Tallent's research has been influential in shaping the practice of sport scientists and strength and conditioning coaches in professional cricket, with impact realised at domestic, national, and international levels. The England and Wales Cricket Board (ECB), as the national governing body for cricket, have adopted the workload monitoring methods that were devised by Tallent and colleagues (3.5). With accompanying findings relating workload to injury occurrence, and team injury status being associated with likelihood of match and tour success (3.4), the ECB now monitor, record, and manage workload of their players to

reduce injury risk. Since applying Tallent's research findings to monitor and manage workload, there has been a reduction in injury rates of England players on international tours, with Tallent's research acknowledged as "undoubtedly contributing to England's team success" in international series and tours (**5.7**). The ECB are also responsible for developing best practice of strength and conditioning coaches working in domestic county cricket and have disseminated Tallent's research findings on workload monitoring, injury, and performance to over 40 coaches who support over 300 professional cricketers and thousands of youth players (**5.7**), meaning impact has been realised domestically as well as nationally and internationally. County cricket coaches acknowledge the impact of Tallent's research in their practice (**5.8**). Coaches monitor and record workload to ensure players are not overloaded and placed at undue risk of injury and to maximise their performance potential- employing specific strategies such as player rotation to realise this (**5.8**). As with the national team, county cricket coaches identify Tallent's research as contributing to improved performance of players and team successes as well as stating that Tallent's research has improved health and wellbeing of players (**5.8**).

The validated method to assess training load in ballet dancers (3.6) has been adopted by The Royal Ballet Company at The Royal Opera House who employ over 100 professional dancers. With similarity to the example of professional cricket outlined above, this means their practitioners have increased knowledge and understanding of the workload accumulated by their dancers. This knowledge is being employed to reduce risk of injury to dancers and optimise their performance effectiveness. Specifically, data collected is being used to inform how rehearsals and performances can be best scheduled to manage dancers' workload and lessen risk of injury. Practitioners within the healthcare team are now able to gain an accurate picture of class and rehearsal intensity as well as quantify individualised accumulated workloads, meaning training schedules can be managed at an individual level to a) reduce risk of injury, b) ensure each dancer is optimally prepared for performance, and c) make it easier to graduate a return to dance post-injury. Further, using epidemiology research from St Mary's, the Royal Ballet Company have identified common sites and mechanisms of injury in their dancers which has led to the development and application of targeted injury prevention programmes (**5.9**).

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

5.1. a. Testimonial from Toby Smith, MSc, MMACP, Technical Lead Physiotherapist at the EIS, and b. The English Institute of Sport's blood flow restriction training policy.
5.2. Collection of testimonials from national sporting governing bodies a. RFU, Remi Mobed, Performance Lead of England Men's Rugby 7s, and Ben Lonergan, Head of Strength and Conditioning of England Women's Rugby 7s; b. Dr Ben Rosenblatt, Lead Physical Performance Coach for the F.A.; c. Dan Lewindon, Head of Performance Science & Medicine for the LTA and British Tennis.
5.3. Testimonial from Dr Joao Viana, Coordinator of Knowledge and Innovation in the Human Performance Department at Sport Lisboa e Benfica.
5.4. Testimonial from Dr Paul Read, clinical research scientist and Head of Clinical Research at Aspetar Orthopaedic and Sports Medicine Hospital, Doha, Qatar.
5.5. http://www.apta.org/patientcare/bloodflowrestrictiontraining/ Website of the American Physical Therapy Association outlining their inclusion of blood flow restriction training as part of the professional scope of practice for physical therapists and directing physical therapists to guidelines written by Dr Patterson.
5.6. Testimonial from Jonny Owens, CEO and Director of Clinical Education at Owens Recovery Science Inc.
5.7. Testimonial from Rob Ahmun, Lead S& C, England & Wales Cricket Board.
5.8. Collection of impact testimonials from County Cricket coaches (John Sadler, Assistant Head Coach, Northamptonshire CCC; Jack Murfin, Head of S&C, Warwickshire CCC)
5.9. Testimonial from Shane Kelly, Clinical Director at Royal Ballet Company, The Royal Opera House.