

Impact case study (REF3)

Institution: Teesside University		
Unit of Assessment: 3		
Title of case study: Changing how training responses are monitored and used in elite team sports through co-produced research		
Period when the underpinning research was undertaken: 2014-2020		
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:
Professor Greg Atkinson	Professor of Health Sciences and Biostatistics Research	Mar 2012 to present
Dr Matthew Portas	Senior Lecturer in Sport and Exercise Science	Oct 1997 to present
Professor Iain Spears	Professor in Sport and Exercise	May 1999 to Jul 2017
Dr Matthew Weston	Reader in Exercise Science	Sep 2009 to present
Period when the claimed impact occurred: 2014-2020		
Is this case study continued from a case study submitted in 2014? N		

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

Athlete unavailability due to fatigue can ultimately compromise team performance and have economic consequences. For instance, it is estimated that an English Premier League Football Club loses an average of GBP45,000,000 per season due to athlete all-cause unavailability. The impacts detailed in this case study are based on research which underpins systems of monitoring athlete responses to training loads, which are known to be associated with 'over-reaching' (fatigue from supra-optimal training loads). Between 2014 and 2020, research at TU into elite athletes' responses to training (co-produced with coaching, support staff and/or technical experts) was undertaken leading to changes in the practice of national and international elite sports teams along three pathways. First, research has changed the practice of monitoring individual athletes' responses to training loads. Use of differential rather than single-item global ratings of perceived exertion (RPE) has led to better-informed decision making about elite team athlete's training loads. Second, our research has changed the practice of monitoring elite youth footballers' movement quality profiles. Support staff and coaches of elite youth team sports athletes now use the Athletic Movement Analysis Tool (AMAT) to gather an improved quality of data as a means of assessing the athletes' responsiveness to training as they mature. Finally, our research has changed the content and practice of an athlete 'wellness' monitoring system in an elite English Premiership Football Club. Development of a new system, based on personalised wellness profiles, changed the way the club identifies athletes as being at risk of fatigue and impaired performance. The impacts detailed demonstrate the usefulness of studying athletes to optimise human well-being and overall system performance in the context of classical human factors (ergonomics).

2. Underpinning research (indicative maximum 500 words)

In elite team sports, the aims of training are to place athletes on the pitch in optimum physical condition to maximize their skills and to prepare them for managing the extreme physical demands associated with playing. Sensitive and precise monitoring of athletes training loads and associated psychophysiological responses is crucial for realizing these aims. Because maximal physical performance assessments, e.g., repeated sprints and jumps, are often not feasible in team-sport environments due to their exhaustive and time-consuming nature, time-efficient, simple, and less invasive tools, such as subjective ratings and movement analyses, are increasingly preferred and have been shown to be sensitive to changes in training load. Research on this topic was undertaken at Teesside University along three pathways - all with

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common features of co-production with support/technical staff, as well as application to elite team sports athletes.

Single item (global) ratings of perceived exertion (RPE) are used widely by sports science practitioners but show poor sensitivity in response to the highly variable external match loads in team sports (e.g., high speed running, sprinting). Differential ratings of perceived exertion (dRPE) comprise separate ratings for physical and technical match demands and, therefore, may provide practitioners with a more sensitive evaluation of their athletes' psychophysiological responses. We undertook the first appraisal of the use of dRPE in team sports, quantifying training loads of players in professional Australian Rules Football - a sport with high physical and technical match loads [3.1]. The research found that athletes differentiated between the feelings of breathlessness, muscle exertion, and technical exertion that comprise dRPE. Because dRPE represented these distinct sensory inputs, it was concluded that dRPE enriched the interpretation of match loads. As team sport match demands are influenced by contextual factors (e.g., playing position, quality of opponents, match location), further research was conducted which led to the conclusion that athlete position and opposition quality also influenced dRPE scores [3.2]. To maximise the utility of dRPE "in the field", we used gaming technology to build a cloud-based mobile app, created within the Unity3D gaming engine, that would facilitate the effective collection of large amounts of dRPE data, e.g. from a full team of athletes.

Youth football Academies must be able to determine whether the prescribed training of youth athletes translates to the effective and efficient movements that are fundamental to senior elite performance. A commonly used assessment was the Functional Movement Screen (FMS). However, our research showed that maturity status had a substantial effect on FMS performance, and that the standard FMS assessment is invalid for very young players [3.3]. Elite football academies enlist adolescents at very early stages of development and these young athletes do not always progress to become well-rounded and robust athletes with good movement quality. Lack of physicality (or movement quality) at the end of adolescence is currently among the main reasons for deselection from academies. A further problem with the FMS is its subjectivity and categorical rating system, with often substantial variance in scoring between testers of different skill and experience.

This research prompted a proof-of-concept study of a single low-cost depth-sensing camera for the real-time measurement of 3-D linear and angular pelvic and trunk range-of-movement [3.4]. These studies [3.3 and 3.4] informed an Innovate UK Knowledge Transfer Partnership (KTP) research grant in collaboration with Pro Football Support Ltd - an athletic development company that delivers benchmarking fitness testing on a manual, consultancy basis for many football academies including the premier league. This KTP led to the development of a unique motion tracking technology system designed to improve movement quality in young elite athletes through testing, analysis, and training: Athletic Movement Analysis Tool (AMAT). Preliminary testing of the within-session movement reliability of the AMAT system has shown that prior habituation is required to obtain precise measurements [3.5]. The AMAT system removes subjectivity in scoring and provides a continuous rather than categorical outcome measure.

Management of fatigue is also important in mediating adaptation to training and ensuring the athlete is prepared for competition, as well as for reducing the athlete's susceptibility to non-functional overreaching, leading to fatigue and unavailability to play. Atkinson was a co-applicant on a funded project, co-produced with coaching and support staff of the first team squad at Manchester United Football Club (Man Utd).

The underpinning research (supported by a research contract with Man Utd) quantified how sensitive a range of wellness and fatigue variables were to changes in daily training load in elite football athletes. The mean daily changes in training load and parallel changes in potential fatigue measures were quantified across in-season training weeks, with perceived ratings of wellness - but not heart rate-derived indices - being sensitive to the fluctuations in training load [3.6]. This research informed practitioners about the most sensitive suite of wellness ratings to use routinely in day-to-day training so that athletes at risk of over-reaching could be identified robustly, thereby informing intervention by coaching staff, e.g., prescription of different training loads.

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

[3.1] Weston M, Siegler J, Bahnert A, McBrien J, Lovell R. 2015. The application of differential ratings of perceived exertion to Australian Football League matches. *J Sci Med Sport*. 18, 704-708. <https://doi.org/10.1016/j.jsams.2014.09.001>. Cited 59 times (Web of Science).

[3.2] Barrett, S, McLaren, SJ, Spears, IR, Ward, P, and Weston, M. 2018. The influence of playing position and contextual factors on soccer players' match differential ratings of perceived exertion: a preliminary investigation. *Sports*. 6:1, 13. <https://doi.org/10.3390/sports6010013>. Cited 11 times (Web of Science).

[3.3] Portas MD, Parkin G, Roberts J, Batterham, AM. 2016. Maturation effect on Functional Movement Screen™ score in adolescent soccer players. *Journal of Science and Medicine in Sport*. 19:10, 854-858. <https://doi.org/10.1016/j.jsams.2015.12.001>. Cited 26 times (Web of Science). Selected for REF2021.

[3.4] Macpherson TW, Taylor J, McBain T, Weston M, Spears IR. 2016. Real-time measurement of pelvis and trunk kinematics during treadmill locomotion using a low-cost depth-sensing camera: A concurrent validity study. *Journal of Biomechanics*. 49: 3, 474 – 478. <https://doi.org/10.1016/j.jbiomech.2015.12.008>. Cited 11 times (Web of Science).

[3.5] Laas MM, Wright MD, McLaren SJ, Eaves DL, Parkin G, Portas MD. 2020. Motion tracking in young male football players: a preliminary study of within-session movement reliability. *Science and Medicine in Football*. 4:3, 203-210. <https://doi.org/10.1080/24733938.2020.1737329>.

This research was underpinned by a Knowledge Transfer Partnership. grid.423443.6. KTP009965. 2015. 2015. [Development of a musculoskeletal training tool for young athletes](#). Principal Investigator: Portas. Co-Investigator: Spears. Partner: Pro Football Support Ltd. GBP108,279.

[3.6] Thorpe RT, Strudwick AJ, Buchheit M, Atkinson G, Drust B, Gregson W. 2016. Tracking morning fatigue status across in-season training weeks in elite soccer players. *International Journal of Sports Physiology and Performance*. 11:7, 947-952. <https://doi.org/10.1123/ijsp.2015-0490>. Cited 53 times (Web of Science).

This was underpinned by funding from Manchester United Association Football Club. 2011. Principal Investigator: Gregson (LJMU). Co- Investigator: Atkinson. [Development & Application of a Customised Prediction Model for Player Availability](#). GBP117,000.

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

The underpinning research has led to changes in the practice of national and international elite sports clubs in terms of the systems they use to monitor athlete responses to training loads. Specifically, the research has led directly to changes in the way sports science practitioners monitor athlete perceived exertion, movement quality and training responsiveness, and wellness.

The underpinning research [3.1 and 3.2] has caused a change in practice of training load monitoring in elite team sports at club level in the UK and internationally, and at national team level. Hull City Tigers Football Club, Philadelphia Union (USA Major League Soccer), Welsh Netball and, most recently, British Cycling have all adopted dRPE to help monitor training loads, and record data using the software Application (App) that was developed from the underpinning research. The possession of better quality and more readily available data that the App facilitates means that coaches now say they have a better understanding of athletes' responses to training loads [5.1, 5.2, 5.3]. The research confirmed that dRPE is a more accurate measure of training load and the move to dRPE from general (global) RPE has provided clubs with better quality data on their athletes' responses to training and matches. For example, Hull City Tigers stated that 'the lack of nuance with global RPE was a problem that as practitioners we wanted to solve and also help us to be more sensitive to changes within an athlete's training loads... Using the dRPE App it has helped resolve a lot of these issues and has allowed us to observe our athletes using greater sensitivity' [5.1]. Philadelphia Union have also incorporated dRPE into their existing battery of training measures and in addition to providing them with better quality

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data on perceived training load, they have used it to enhance understanding of other measures that they routinely take: 'dRPE has been a great addition to our current practices, as it adds a further level of context and understanding to the data already collected' [5.2].

The dRPE App developed as part of the underpinning research has made dRPE data easier and quicker to collect. The App automatically stores data in an exportable spreadsheet, replacing the previous method of manual input so that large amounts of data are more readily available. This has led to improved decision-making of coaches and training staff with respect to athletes' training needs. Hull City Tigers now routinely use dRPE data to inform their training responses to injured athletes: 'within our rehab process, dRPE can be used for both evaluating and prescribing loads depending on the type of injury' [5.1]. Philadelphia Union tailor preparations and treatments for athletes based on the dRPE data that they collect: 'the collection of this [dRPE] data has benefitted us in the backroom/medical staff, as it allows us not only to talk about "how hard" a session was, but now discuss "where" the session hit players hardest. This also allows us to focus treatments (medical, massage, etc.) or tailor preparations (warm up, gym work, etc.) based on how players are perceiving this work' [5.2]. The use of dRPE allows coaches to provide individualised plans for athletes for both rehabilitation and to maintain their ability to manipulate the "dose", or external load, of physical activity that athletes are given in order to continue to increase their fitness levels.

A Senior Physiologist with the English Institute of Sport used dRPE for his support of netballers' training and competition, and more recently in his role as Senior Physiologist with the Great Britain Cycling Team. He said that dRPE was 'superior to session RPE, providing a greater level of insight into the demands experienced by performers...I used dRPE to better understand the demands of netball training and competition, and found differences between playing positions, an insight which sRPE could not provide' [5.3]. In terms of the use of the App itself, he said: 'the App in particular has been of great value. A key challenge we face as practitioners working in elite sport is the acquisition of accurate and reliable data and exporting this into a useable format. The app assists greatly in permitting quick and easy data collection from the athletes, and in easily exporting this to be analysed and interpreted' [5.3].

AMAT technology, developed as part of the underpinning research [3.5], has been adopted by elite youth football academies at a club level in the UK and internationally, including Middlesbrough Football Club in the UK [5.4]. The research has led to a change in practice in the type of data gathered by these Academies on youth footballers' movement quality profiles and how the data are collected. These data are essential for coaches to understand how the training that youth footballers receive affects the movement qualities that athletes are required to master to succeed in professional football. Before the introduction of AMAT, there was no available method of detailed biomechanical analysis of movement performance, and existing methods were subjective, time consuming, and lacking in nuance. The use of AMAT has provided clubs with a portable, comprehensive, movement screening tool that captures accurate, fine grained data quickly and objectively [5.4, 5.5]. This technology benefits coaching staff by allowing them to test a number of athletes quickly and accurately, meaning that time taken out of a training session for screening is reduced and, as a result, testing can take place more frequently. The Head of Academy Science and Medicine at Middlesbrough FC said she observed more reliable, detailed, and faster data capture when 'data was collected on our players within our category 1 Elite Player Performance Pathway (EPPP) academy' [5.5]. Because AMAT is automated and standardised, clubs can obtain objective data without tester variability. This has provided better availability of high-quality data for coaches and led to their better understanding of athletes' responses to training. The Head of Academy Science and Medicine at Middlesbrough FC said using AMAT during the 19-20 season provided her with 'a deeper understanding of players movement qualities using a higher accurate detailed system' [5.5].

The impacts to Pro Football Support (part of Pro Sport Support Ltd; PSS) from developing and using AMAT as part of their consultancy services included significant productivity gains, as digitisation of their existing services to elite footballers is now less time consuming, more accurate, more repeatable, and therefore more reliable. The Managing Director of PSS has reported that the research collaboration 'meant that the AMAT system was developed' which led to two patents (Patent: GB 1703243.4 February 2017, and Patent: WO PCT/GB2017/053899

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December 2017) and helped to 'diversify our business offer and also ensure that the athlete support we provide elite youth sport has an enhanced movement assessment offer' [5.4]. Sales of AMAT have occurred on a global scale, including Hungary, Greece, Spain, Portugal, and China and the Managing Director of PSS said that the AMAT is a 'huge development in this field of performance monitoring' and anticipated it as 'being highly profitable for our business' [5.4].

The underpinning research has also changed the way that athlete support staff at Manchester United Football Club monitor the daily "wellness" ratings from athletes [5.6]. The underpinning research informed which indicators of wellness were most sensitive to changes in training loads and match loads [3.6]. This led to the most appropriate and robust suite of measures being selected. These wellness measures were useful to staff because there is a trade-off relationship between adaptation to, and recovery from, training, which can be difficult to quantify, especially when evaluating potential injury risk for athletes. The wellness monitoring system that resulted from the research was said by staff to help identify individuals at risk of 'over-reaching' during training, and to delineate the extent of the stress experienced by the athlete. The Head of Physical Performance at Man Utd FC has stated that 'the research [3.6] was instrumental in examining the efficacy of various techniques that could be applied with our players on a daily basis to better understand their physical condition' [5.6].

As the underpinning research indicates, athletes will respond differently to varying training loads. Therefore, the research led staff to appreciate that a "one size fits all" decision making approach was not appropriate. The suite of wellness ratings was, therefore, incorporated into a decision-making system centred on individual "response fingerprints" informed by the within-athlete changes in wellness described in the research output. This led to a surveillance system that provided insights on readiness to train and compete on a daily basis. The Head of Physical Performance explained that 'as a direct consequence of the research we changed our assessment approach at Manchester United and adopted these measurement techniques with the first team squad in our daily practice' [5.6]. This change in practice not only improved their ability to evaluate a player's readiness to train and compete but also led to a reported increase in player availability for matches of approximately 14% over three competitive seasons [5.6].

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

[5.1] Email (pdf). Testimonial from a first team Sports Scientist at Hull Tigers FC regarding the beneficial impact of dRPE to training and match load monitoring procedures and use of the dRPE App. Received on 23 April 2018.

[5.2] Signed Letter (pdf). Testimonial from the Director of Performance at Philadelphia Union FC regarding the beneficial impact of dRPE to the clubs training load monitoring procedures. Received on 20 April 2018.

[5.3] Signed Letter (pdf). Testimonial from Senior Physiologist at the English Institute of Sport relating to the incorporation of dRPE into elite athlete monitoring practice with Welsh Netball and British Cycling. Received on 2 December 2020.

[5.4] Signed Letter (pdf). Testimonial from Pro Sport Support Ltd (pdf) relating to the development of the AMAT system, global sales and associated patents. Received on 14 January 2021.

[5.5] Signed Letter (pdf). Testimonial from Head of Academy Science & Medicine, Middlesbrough FC. Received on 15 January 2021.

[5.6] Signed Letter (pdf). Testimonial from Head of Physical Performance, Manchester United FC. Received on 21 January 2021.