Institution: University of Essex		
Unit of Assessment: 24 - Sport and Exercise Sciences, Leisure and Tourism		
Title of case study: Enhancing Sports Performance, Coaching and Organisational Practice, Culture and Economic Growth		
Period when the underpinning research was undertaken: 2013 - 2017		
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:**
Ben Jones	Lecturer, Sports Performance & Coaching	2015 – Present
Chris Cooper	Professor, Sport & Exercise Science	1995 – 2018
Daniel Coughlan	Lecturer Sports Therapy	2016 – 2020
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

Essex sports research, by utilising novel physiological and biomechanical measurements in elite athletes, underpins changes in coaching and organisational practice, which result in improvements in elite athlete performance with associated cultural and economic impacts. This case study highlights **six examples within three elite sports** where Essex research has underpinned the impact. For **England Golf** and players of the **PGA European Tour** development, validation and implementation of new training, profiling and warm-up protocols which were adopted by 100% of players, led to wins for all England golf squads at the Home Internationals and 2nd in the European Team Championships in 2018 and, since 2018, 12 players have won an event in PGA European Tour. For International field hockey teams (**Team GB** & **Team USA**) new training protocols improved sports performance in National, International and Olympic competitions (Rio 2016), with Team GB moving from bronze to Olympic gold and Team USA moving up from 12th to 5th. For elite **synchronised swimming** the use of novel physiological measurements had cultural impacts by being showcased in a multi-award winning science documentary (**NHK Japan**) watched by 21.3 million people in Japan (receiving six National and International awards). For European high technology SME (**Artinis Inc. Netherlands**) the showcasing of the use of new equipment by Essex research in elite athletes resulted in economic impacts, increasing sales (GBP 250,000).

2. Underpinning research

The primary aim of the Essex Sports Performance Research Group is to provide evidence-based research to understand, inform and drive improvements in athlete success; secondary aims include enabling economic activity arising from our research and facilitating public and cultural engagement in the science of sports performance. **This impact case study utilises six examples within three elite sports to highlight Essex research in this area:**

Elite Golf

From 2016 till present, Coughlan was a consultant with England Golf and the European Golf Tour. Therefore, even prior to publication, these organisations were able to apply his original research (described below) on elite golfers to inform their practice and improve performance. Coughlan's work on athlete profiling in golf [R1, R2] revealed that the previous use of jump height to inform greater driving distance was flawed, due to its penalisation of high body mass; he showed that countermovement jump impulse or jump power are more strongly related to club head speed and should be used instead, especially when combined with medicine ball throws and isometric mid-thigh pulls. In [R2] Coughlan further highlighted key physical attributes which should be assessed and relate to club head speed in high level youth golfers. Where previous research in this area had little impact, this unique publication was undertaken in a key developmental area with an elite cohort. It was therefore directly relevant to National Governing Bodies. In [R3] Coughlan demonstrated how a simple and player accessible, range based warm up could improve club head speed and shot quality, both important determinants in golf play outcomes. Research into this specific group of young elite athletes is rare and highlighted the usefulness of these tests when looking to improve club head speed. In [R4] Coughlan evidenced that training only once per week is sufficient to support meaningful changes in club head speed in youth golfers. Given the limited strength and conditioning time given to youth golfers, this finding into training dose and response

held real and direct value for practitioners and players in terms of training effectiveness.

Elite Hockey

Cooper's Near Infrared Spectroscopy (NIRS) research on elite athletes' training adaptations following high intensity training led Team GB women's field hockey's strength and conditioning (S&C) coach to engage Essex to develop and validate new training approaches for Team GB hockey. Cooper and Jones did so, reporting the first measurements of muscle oxygenation and haemodynamics in individual Olympic athletes in response to a sprint interval cycling training programme approach [R5]. This work was significant because the use of NIRS to detect training effects in response to exercise is usually reported as group data, within untrained or recreationally active cohorts. [R5] showed that NIRS can report on training induced changes in individual elite athletes and further how it can be used to evaluate the effectiveness of future sport performance enhancing practices. Additionally, this work evidenced and validated the development of a low volume, time efficient, bike training protocol that led to enhanced muscle oxygen consumption; the subsequent increase in running performance in elite hockey players, was significant given the rarity of previous research evidencing such a performance effect in elite athletes.

Underwater Physiology Measurements in Elite synchronised swimming

NIRS technology had been exclusively used within "dry" applied sport & exercise fields, the lack of waterproofing preventing use in more challenging aquatic environments. In 2013, however, Cooper began the development, testing and *in vivo* validation of a new waterproof NIRS device, facilitating measurements in previously inaccessible exercise settings [R6]. The exemplar paper by Cooper and Jones [R6] showed that, using appropriate caution, adaptations could be made to NIRS devices that enabled underwater measurements equivalent to those on dry land. NIRS use was well tolerated and yielded interesting physiological measures during cold water immersion and sprint swimming in club level athletes and triathletes. This research therefore described the first use of NIRS to measure muscle oxygenation during swim exercise and enabled the future use of NIRS technology to provide novel physiological measurements in an aquatic environment.

3. References to the research [can be supplied by HEI on request]

R1 Wells JE, Charalambous LH, Mitchell AC, Coughlan D, Brearley SL, Hawkes RA, Murray AD, Hillman RG, Fletcher IM. Relationships between Challenge Tour golfers' clubhead velocity and force producing capabilities during a countermovement jump and isometric mid-thigh pull. Journal of Sports Sciences. 2019 Jun 18;37(12):1381-6. https://doi.org/10.1080/02640414.2018.1559972

R2 Coughlan D, Taylor MJ, Jackson J, Ward N, Beardsley C. Physical Characteristics Of Youth Elite Golfers And Their Relationship With Driver Clubhead Speed. The Journal of Strength & Conditioning Research. 2020 Jan 1;34(1):212-7. https://doi.org/10.1519/JSC.0000000000002300

R3 Coughlan D, Taylor MJ, Jackson J. The impact of warm-up on youth golfer clubhead speed and self-reported shot quality. International Journal of Sports Physical Therapy. 2018 Aug; 13(5):828. PMCID: PMC6159497

R4 Coughlan D, Taylor M, Wayland W, Books D, Jackson J. (2020). The effect of a 12 week strength and conditioning programme on youth golf performance. The International Journal of Golf Science. 8(1) https://www.golfsciencejournal.org/article/11147-the-effect-of-a-12-week-strength-and-conditioning-programme-on-youth-golf-performance

R5 Jones B, Hamilton DK, Cooper CE. Muscle oxygen changes following sprint interval cycling training in elite field hockey players. PloS One. 2015 Mar 25;10(3). https://doi.org/10.1371/journal.pone.0120338

R6 Jones B, Dat M, Cooper CE. Underwater near-infrared spectroscopy measurements of muscle oxygenation: laboratory validation and preliminary observations in swimmers and triathletes. J of Biomed Opt. 2014 Dec; 19(12):127002. https://doi.org/10.1117/1.JBO.19.12.127002

4. Details of the impact

We evidence six examples (**highlighted in bold below**) of our research's impact within three elite sports: physical profiling and training interventions in golf research, both amateur (**England Golf)**) and professional (**PGA European Tour**), changing organisational practice leading to enhanced performance; non-invasive muscle optics physiological monitoring improving elite **Team GB** & **Team USA** hockey players' performance; underwater NIRS use in synchronised swimmers

benefitting creativity, culture and society by enabling the co-creation of a new cultural artefact for **NHK Japan**; and research improving the economic performance of a business by contributing to entrepreneurial activity and improving existing products for **Artinis Inc**.

England Golf and European Tour - Research led to a change in organisational practice leading to improved sports performance

England Golf [S1, S2]

Athlete profiling by Coughlan [R1, R2] revealed that the previous use of jump height to inform greater driving distance was flawed. England Golf consequently trained eleven staff in this area and now use isometric mid-thigh pulls and countermovement jump to profile all of their National players and medicine ball throws and countermovement jump power to profile all regional players. The demonstration in [R3] that a standardised warm up led to longer, more accurate drives led to its adoption by England Golf for all players in the England system. [R4] showed that even if youth golfers only train once per week, it has a meaningful positive impact on their club head speed and drive distance; this directly led England Golf to encourage all regional programmes to deliver face to face weekly S&C sessions. Equipment was purchased and all S&C staff trained to complete testing according to [R1] and interpret the results and provide training recommendations based on [R3] and [R4]. According to the Lead S&C Coach at England Golf, Essex "*research has helped us define our programmes sport science support*" [S1].

Coughlan then collaborated with England Golf to develop new physical profiling protocols [S2]. In profiling, England Golf now require all S&C staff working with national players and players in regional squads to complete physical profiling using key measures from [R1] & [R2] [S2]. They add "*profiling tests from your first study looking into the physical characteristics of players have been incorporated across all regional squads, with 100% uptake. These profiling tests are now used across ~200 regional under 18 players twice annually and have been since 2017. The results from the profiling are being used to provide training goals and specific training recommendations to all regional players and form a significant part of how we evaluate the effectiveness of our regional strength and conditioning support"* [S2]. They noted *"100% of our 40 national level players complete these profiling tests twice annually, from which they receive specific training advice to advance their performance*" [S2].

In terms of warm up, "*your research into the effectiveness of warm-up in golf [R3] has been used as the foundation for our nation-wide approach to warm-up education for the players in both regional and national squads [S2]. All players (~240 across the programme) are taught the warm-up used in your study [R3] when they enter our pathway and are expected to use that or variants of that warm-up throughout the competitive season*" [S2].

In S&C, "*your research into the effectiveness of strength and conditioning training [R4] has helped us to develop and justify resourcing strength and conditioning coaches to deliver once-weekly sessions for players in the regional programme. This is now our preferred delivery strategy, especially in the off-season*" [S2].

In terms of performance outcomes, England Golf have noticed a dramatic increase in success following the policy changes introduced as a result of the recommendations in [R1-R4]: "*Over the past year [to July 2020], we have had incredible success as a nation, including wins for all squads (Women's, Girls', Men's and Boys') at the Home Internationals and placing 2nd in the European Team Championships Our players are hitting the ball further; we are seeing injuries less frequently and we are commonly observing more positive training and warm-up behaviours*" [S2]. The research "*played a significant part in achieving the world leading success England Golf has enjoyed and had it not been for your work the quality of our sports science support and results achieved would not have been possible. This research has allowed us to gain a major performance advantage on the international stage*" [S2].

European Tour [S3, S4].

According to Director of the European Tour Performance Institute (ETPI) "*In 2017, as a consequence of our discussions with Essex's sports performance research team and on the basis of the evidence in their work, we began using a predicted countermovement jump peak power measure of explosive strength*" [S3]. Coughlan then collaborated with the Tour to develop new physical profiling protocols for ETPI, [S4], based on and referencing [R1 & R2]. Coughlan facilitated the implementation of his research to PGA European Tour members via ETPI so that

they could implement the protocols outlined in [R3] and [R4]. Specifically ETPI "*purchased the required equipment to mimic the testing methodologies used in your club head velocity and force paper. We took on contractors to supply strength and conditioning support to players, and you trained and supported them directly, so they could deliver the standardised profiling assessment used in your work*" [S3]. Profiling based on the recommendations from Essex research [S4] "*is now offered free of charge, to all 650 players who compete under the PGA European Tour and its associated tournaments"* [S3].

According to ETPI, Coughlan's research directly resulted in "*organisational level change and practitioner level change in practice regarding profiling and training for players*" [S3]. The increased knowledge gained about optimising golf physical preparation as a result of [R1-4] and "*helped inform the facilities we offer at events*" [S3]. Notably "*at the 2018 and 2019 Open Championship as well as the victorious 2018 and up-coming 2020 [now 2021] Ryder Cups, the PGA European Tour and R&A have provided and will continue to provide bespoke training facilities, tailored to the needs of players, based on your research*" [S3].

ETPI have noted significant associated performance outcomes. "*During any given tournament, approximately 25% of the total field will have been through the physical profiling assessment to inform their training. Since 2018, 12 players have won an event following training recommendations directly related to the profiling they received. Most of the players we profile, who follow the tailored recommendations, report meaningful increases in their driving distance, which gives them an important competitive advantage*" [S3].

Elite Hockey Team GB + Team USA (change in coach methods & teams' performance) [S5]

Seeking to enhance the performance of Team GB women's field hockey, their S&C coach contacted Essex in 2013 to explore the use of NIRS to test new training adaptations and devise a protocol for them prior to the 2016 Rio Olympics [S5]. They were especially interested in Cooper's previous use of NIRS in research testing performance in elite rugby players: "*the use of off-feet (bike) training had resulted in both performance and peripheral muscle adaptions, suggesting that such an additional training load can be introduced without the need for impact (run) training*" [S5]. Crucially, Essex research had demonstrated that "*bike training can yield improvements in such [elite] athletes*" and that "*the use of NIRS analysis meant that information could be obtained at the peripheral level, which is of interest to a practitioner like me*" [S5]. In collaboration with Team GB women's field hockey, a specific training programme was devised and validated by Cooper's research, subsequently published in [R5]. The new training methods were implemented in Team GB hockey players from 2014 onwards. This had a "*notable effect on the player's physical capacity*", "*increased the player's final running velocity*" and "*capacity to undertake more high intensity efforts*", which the coach believed was "*a key determinant in winning matches*" [S5]. Crucially "*the players did not experience injuries or overtraining as a consequence*" [S5]. This Essex research changed the S&C coach's whole "*approach to training regimes for high intensity efforts*" [S5]. When he subsequently moved to be Head of Performance Science for Team USA women field hockey, they "*implemented training protocols from 2014-2016 based upon University of Essex research*" that "*resulted in notable improvement in the players capacity to improve high intensity efforts and thereby increased their ability to sway decisive points to their advantage. During this time the team improved, raising their Olympic performance from 12th in London 2012 to 5th in Rio 2016, earning fourth place at the 2014 World Cup and winning the gold medal in the FIH (Federation Internationale Hockey) championship challenge in May 2014. Performance gains in elite athletes already near their limits are hard to achieve, nevertheless, the insights from working with your group gave us such advantages*" [S5].

The "novel insights" [S5] from Essex research [R5] therefore improved a coach's approach, leading to changes in training programmes for two national field hockey teams. Indeed, without Essex's contribution these teams "*would have lacked an advantage in a critical aspect of their performance for international competitions*" [S5].

Enabling physiological measurements in elite synchronised swimmers: impact on creativity, culture and society by co-creating TV programme (new cultural artefact) [S6-8]

The demonstration by Cooper and Jones that NIRS could be used successfully underwater [R6] directly led the Production Research Manager from Japan's national broadcasting organization (NHK) to contact Cooper in January 2016 to discuss aiding with the scientific content for a new TV

programme - “Russia’s Golden Mermaids”. This formed part of the Japanese public broadcaster NHK’s highly successful “Miracle Body” Series focussing on the science underpinning performance in elite synchronised swimming [S6]. Jones continued these discussions; assisted with the planning of the programme; personally took the oxygenation measurements on the muscle and brains of swimmers in Tokyo and Barcelona that featured extensively as key visuals in the programme [S7]; and explained the meaning of the data to the production team and on camera to the TV audience. As noted by Konishi “*Ben was invaluable to us not only for the data acquisition but also in interpreting the data obtained from these tests*” [S6]. His analysis featured extensively in the finished programme as helping “*immensely in translating scientific methodology and analysis into language which could be appreciated by our general public audience*” [S6]. NHK considered the programme highly successful as it received above average viewing figures for a NHK special documentary of 6.6% (9.9 million) in the Kanto (around Tokyo) area, and 7.6% (11.4 million) in the Kansai area and was syndicated in six other countries [S6]. “Russia’s Golden Mermaids was praised by critics winning six national and international awards [S6], most noticeably the Takayanagi Grand Prix Prize for best TV science documentary prize in Japan (2016), the “Silver Screen”. In the year following the documentary (2017), the Japanese Swimming Federation saw a 5% increase in registered synchronised swimmers, against a backdrop of a fall in other registered swimmers [S6, S8 p11].

Artinis Inc. economic impact via contributing to innovation and entrepreneurial activity and improving the performance of a business through improvement of existing products [S9]

Artinis Inc. (established 2002) are a Dutch SME with approximately 50 employees that manufacture innovative NIRS systems for muscle and brain oxygenation measurements. For over 10 years they have had a close working collaboration with Cooper and Jones and the CEO notes that “*The University of Essex research group have been instrumental in our product design and algorithm” and the collaboration has led to “innovative product design and advancement*” [S9]. Artinis consider Cooper’s research team “*world leading in the applied work that they conduct*” with Artinis products [S9] and when contacted by potential customers “*we always mention the special work by the University of Essex in speed skating, sport and elite sport*”. The company uses Essex research on elite athletes (e.g. [R5] as marketing) to enhance sales of their muscle Portamon device. Additional markets were opened by the demonstration that University of Essex modifications of Artinis devices enabled their successful use underwater, both in club athletes [R6] and elite synchronised swimmers (see NHK documentary above). Artinis note that “*As with all new products, market introduction is difficult*” but that highlighting the research of Cooper’s group “*aided with the marketing process*”. The research “*aided in product requests and sales that have benefited the company demonstrably*”, “*increased sales rates in the region of GBP 250,000, which has enabled company growth and increased company employment*” [S9].

5. Sources to corroborate the impact [can be supplied by HEI on request]

England Golf & PGA European Tour (organisational practice/athlete performance)
[S1] Strength and Conditioning Coach, England Golf Lead (2020)
[S2] Physical profiling framework documents for England Golf (2019)
[S3] Director, European Tour Performance Institute (2019)
[S4] Physical profiling framework documents for European Tour Performance Institute (2019)
[S5] Director of Performance Science, USA Field Hockey (2017)
Muscle Optics (creativity, culture and society; co-creation of a new cultural artefact)
[S6] Production Manager, NHK. Miracle Body Series (2020)
[S7] “Russia’s Golden Mermaids” documentary TV programme https://pf.nhk-ep.co.jp/detail/2057 21/01/20, NHK website; programme synopsis, date of airing (2016)
[S8] Japanese Swimming Federation synchronised swimming numbers (Fina)
Muscle Optics (economic impact)
[S9] CEO, Artinis Medical Systems (2019)