

Institution: Liverpool John Moores University (LJMU)		
Unit of Assessment: UOA24		
Title of case study: Protecting the Hearts of our Athletes: from Pre-participation Screening to Secondary Care		
Period when the underpinning research was undertaken: 2002-2020		
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:
Keith George	Professor of Exercise and Cardiovascular Physiology	2002 – present
Greg Whyte	Professor of Applied Physiology	2006 – present
David Oxborough	Reader of Cardiovascular Physiology	2012 – present
John Somauroo	Professor of Sports Cardiology	Cat. C April 2010 to April 2016; Cat. A May 2016 to May 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		
<p>The tragic sudden cardiac death (SCD) of 12 young people (<35 years of age) a week in the UK may be preventable through pre-participation cardiovascular screening (PPS). The research undertaken by the Cardiovascular Health Sciences (CHS) group at LJMU has led to significant change with international reach in athlete PPS including; a) updating international consensus statements (e.g. International Criteria for Interpretation of ECG in Athletes), b) the production of sport-specific evidence-based PPS policies and guidance documents (e.g. GB cycling), and c) the establishment of PPS pathways of care in Liverpool (e.g. Sports Cardiology Clinic) and internationally (e.g. Wadi El Neel Hospital, Egypt). We have made a timely and very significant contribution to changing and improving the cardiovascular care of athletes.</p>		
2. Underpinning research		
<p>The CHS group, in collaboration with multiple partners around the globe, has published a large series of empirical research papers (N=395), of which many have contributed directly to change in PPS guidelines and applications in screening programmes in the UK and around the world. The key outputs and research insights that underpinned and influenced the developments and changes described in this impact case study are outlined below.</p>		
a) Research underpinning International Consensus Documents/Position Stands/Expert Criteria		
<p>CHS staff contributed 5 original research articles to the development of the “International Criteria for Interpretation of the ECG in Athletes”. Exemplar original research included a paper (KG/GW) in 2014 completed in collaboration with colleagues in Qatar that highlighted that current ECG criteria can be applied to athletes of Arab ethnicity (Sec.3, Ref.1). This paper, therefore, extended the coverage of PPS screening practice and guidelines in an elite population of athletes that has received less attention than other groups (European, American). This extends the reach of this research focus. A second paper (GW/KG), in over 2400 multi-ethnic athletes who presented for PPS (Sec.3, Ref.2), observed that adopting new Refined ECG criteria, compared to the 2013 Seattle and 2010 European Society of Cardiology (ESC) guidelines, significantly reduced false-positive PPS rates whilst maintaining 100% sensitivity for identification of serious cardiac pathology. These data were unique, and important, in demonstrating empirical support for the developing PPS criteria. This evolution has been important in providing clear data to drive the international reach of this work. New data on right heart structure and function in athletes (2013) by DO and various collaborators continue to define the magnitude of normal cardiac adaptation in</p>		

the athlete (**Sec.3, Ref.3**). This study demonstrated that over 50% of athletes with normal athletic cardiac adaptation have values that overlap with inherited disease. In addition, the data was key in highlighting ethnic and gender differences in the right heart. This paper directly contributed, alongside 8 other research articles from CHS, to the normal ranges used in PPS.

b) Research underpinning impact on PPS Policy

The examination of different echocardiographic screening patterns in athletes has been one of our main research areas. A key study published in 2018 (JS/DO), in collaboration with the FA, assessed PPS screening in 11,168 youth Soccer players between 1996 and 2016 (**Sec.3, Ref.4**) and identified 42 athletes with serious cardiac conditions of whom 8 died during the follow-up period after an initial 'snapshot' PPS. This important finding supported a change in PPS with a move away from a one off 'snapshot' PPS to serial assessments across an athlete's career.

Studies defining the upper normal limits of atrial and right heart size (**Sec.3, Ref.3 and Ref.5**), by DO/KG, highlighted that endurance athletes create the greatest challenge to differentiation from pathology in PPS as it was demonstrated that values in these athletes frequently overlap with pathology. In addition, (**Sec.3, Ref.5**) provided data pertaining to novel indices of atrial function which are subsequently becoming embedded within echocardiographic PPS protocol. Based on these studies amongst others echocardiography was determined to be an integral component of PPS and is utilised at both primary and secondary care of our athletes.

c) Research underpinning impact on PPS provision, and Secondary Care of Athletes

In 2016 JS, in collaboration with St Georges University and Cardiac Risk in the Young, undertook a full efficacy and economic analysis of PPS in 1191 elite rugby players in England. These data highlighted the successful use of onsite echocardiography in reducing referral rates to secondary care and subsequent follow-on costs (**Sec.3, Ref.6**). This study also contributed to the use of ECG only, with onsite echocardiography as clinically required, during PPS. This approach is now commonplace in many sporting organisations.

The availability of appropriate secondary care, as a result of a positive or inconclusive PPS, is fundamental to support the health of athletes. The CHS group produced a range of original research articles, including (**Sec.3, Ref.3, Ref.4**), that impact upon care pathways. These studies demonstrated the impact of ethnicity and age on cardiac adaptation and its overlap with disease. The normative values generated by this work contributes to clinical decision making and the identification of optimal secondary care in athletes such as adolescent soccer players following FA patient pathways. Finally, studies by KG/GW (**Sec.3, Ref.1 and Ref.2**) provided ECG data that contributed to improving sensitivity and specificity of PPS in both primary and secondary care of athletes and have changed best practice that is employed nationally and internationally.

3. References to the research

1. Riding NR, Salah O, Sharma S, Carre, F, **George K**, Farooq A, Hamilton B, Chalabi H, **Whyte G**, and Wilson M. ECG and morphologic adaptations in Arabic athletes: are the European Society of Cardiology's recommendations for the interpretation of the 12-lead ECG appropriate for this ethnicity? *Br J Sports Med* 2014; 48: 1138-1143.
2. Riding NR, Sheikh N, Adamuz C, Watt V, Farooq A, **Whyte G**, **George K**, Drezner J, Sharma S, and Wilson M. Comparison of three current sets of electrocardiographic interpretation criteria for use in screening athletes. *Heart* 2015; 101: 384-390.
3. Zaidi A, Ghani S, Sharma R, **Oxborough D**, Panoulas V, Sheikh N, Gati S, Papadakis M and Sharma S. Physiologic right ventricular adaptation in elite athletes of African and Afro-Caribbean origin. *Circulation* 2013; 127: 1783–1792.

4. Malhotra A, Dhutia H, Finocchiaro G, Gati S, Beasley I, Clift P, Cowie C, Kenny A, Mayet J, **Oxborough D**, Patel K, Pieleles G, Rakhit D, Ramsdale D, Shapiro L, **Somauroo J**, Stuart G, Varnava A, Walsh J, Yousef Z, Tome M, Papadakis M and Sharma S. Outcomes of Cardiac Screening in Adolescent Soccer Players. *N Eng J Med* 2018; 379: 524-534.
5. McClean G, **George K**, Lord R, Utomi V, Jones N, **Somauroo J**, Fletcher S and **Oxborough D**. Chronic adaptation of atrial structure and function in elite male athletes. *European Heart Journal: Cardiovascular Imaging* 2015; 16: 417-422.
6. Ghani S, Papadakis M, Kemp S, Zaidi A, Sheikh N, Gati S, Raju H, Smith A, Palmer C, **Somauroo J** and Sharma S. Results of a nationally implemented de novo cardiac screening programme in elite rugby players in England. *Br J Sport Med* 2016; 50: 1338-1344.

All the research papers are published in high quality, peer-reviewed international journals. In addition, we have received funding from Cardiac Risk in the Young to support 2 PhD students who actively contributed to the CHS portfolio.

4. Details of the impact

Strategic Approach to Dissemination (education, training and public engagement)

With the aim of translating our research to produce impact, the CHS group have engaged in high-profile dissemination activities with multiple end-users throughout the period 2014-2020. This has included clinical, scientific and sports groups in the UK including British Cardiovascular Society, British Society of Echocardiography, British Sports Symposium and globally including European College of Sports Sciences, European Society of Cardiology and the European Society of Preventative Cardiology. We have undertaken PPS training for healthcare practitioners in the UK including St Georges Park and Wembley Stadium for the FA in 2016, 2018 and 2021, annual MSc in Sports Cardiology and the first Cardiac Imaging in Athletes and Cardiomyopathy focused course (2018) at St Georges University, London and annual 2-day PPS workshop at LJMU. We have also delivered internationally at the ASPETAR Conference on Cardiac Screening and Vascular Adaptation in Athletes – Qatar in 2015, Pre-Competition Cardiac Assessment Workshop for Footballers - Saudi Arabia in 2014, Exercise and Sport Science Australia Research to Practice Conference in 2016, Hong Kong Symposium in Sports Medicine in 2016 and Pre-Competition Cardiac Assessment Workshop – Egypt in 2018. Public engagement activity has also been a strategic priority to reach all those involved in sport beyond elite level competition and has included media platforms such as the BBC, Sky Sports, Goal.com, the Conversation, CNN and primetime Egyptian television. Evidence of broad awareness of our research is that key outputs (**e.g. Sec.3, Ref.4**) are in the top 5% of all research outputs scored by Altmetrics (a marker of the attention outputs receive).

a) Impact on International Consensus Statements/Position Stands/Expert Criteria

Through dissemination of research papers, collaboration with key stakeholders and membership of the FA cardiology consensus committee (JS and DO), research from the CHS group at LJMU has had a significant impact on the decision-making criteria/algorithm[s] employed in PPS globally through the production of consensus statement documents, position stands and expert criteria. These documents are a standard method of changing practice and clinical decision marking with respect to PPS. Advancements in practice include developing the predictive capability as well as improving the sensitivity and specificity of specific criteria/algorithms. Important examples of this are the “International Criteria for Interpretation of ECG in Athletes” (**Sec.5, Source A**), the ESC position statements “Recommendations for the Indication and Interpretation of Cardiovascular Imaging in the Evaluation of the Athlete’s Heart” (**Sec.5, Source B**) and ‘Pre-participation Cardiovascular Evaluation for Athletic participants to prevent sudden death’ (**Sec.5, Source C**)

that refer to our research (**Sec.3, Ref 1-4**). These documents have become the standard tools for ECG and echocardiographic interpretation during PPS globally due to their adoption by the International Olympic Committee, FIFA and the Union Cycliste Internationale amongst many global sporting bodies. Over the past 5 years in excess of 2000 athletes have been screened by the CHS group utilising these new criteria and guidelines. In addition, the FA and Cardiac Risk in the Young have screened over 15,000 athletes in the UK employing these updated standards. Although it is difficult to establish the absolute numbers of athletes screened globally, the International ECG Criteria based on our research and others have been adopted by Sports Cardiologists worldwide.

b) Impact on PPS Policy and Education

A direct consequence of the change in global PPS consensus statements has been new adoption or changes to PPS policy documents in many sports organisations and clubs. Empirical research undertaken by members of the CHS group have explored the efficacy, feasibility and outcomes of PPS in football and rugby (**Sec.3, Ref.3 and 6**) and through CHS representation at the FA and the British Society of Echocardiography these have led directly to the production of new PPS policy documents (e.g. GB Cycling; **Sec.5, Source D**) as well as driving changes to treatment pathways (**Sec.5, Source E**). Since 2018, GB Cycling Team have committed to undertaking PPS on all of their athletes every 2 years with 200 cyclists screened since 2018 as part of their initial PPS. Furthermore, the FA have changed their policy, on the basis of consensus panel review (DO/JS) of the developing literature base, to screen scholar players at age 14 years, 16 years and 20 years in order to reduce the risk of a missed developing phenotype of cardiac disease. CHS research (**Sec.3, Ref.4 and 5**) has extended our understanding of the multi-faceted phenotypical presentation of the upper normal limits to physiological cardiac adaptation. These data have been directly incorporated into bespoke educational material and practice guidelines for PPS in the UK. DO has been a member of the Education committee and Chair for the Research and Audit Committee since 2014 and was approached to lead on a guideline document produced by the British Society of Echocardiography and endorsed by the charity Cardiac Risk in the Young (**Sec.5, Source F**). This document has changed the role of echocardiography during PPS of athletes in the UK advocating on-site use, providing best-practice guidelines and a minimum dataset to maximise sensitivity and specificity of the technique. All UK echocardiographers are required to adhere to this policy statement during acquisition and interpretation of images during PPS and at follow-up. This document has been disseminated to over 4000 UK and international members of the British Society of Echocardiography. This has systematically enhanced service delivery in all clinical echocardiography departments in the UK.

c) Impact on PPS provision, and Secondary Care of Athletes

Our research work influenced the development of appropriate and effective cardiac screening processes and guidelines and since 2014 members of the CHS group have undertaken PPS using these guidelines in approximately 2000 athletes from various sporting disciplines and professional sporting organisations across the UK including the FA, Liverpool FC, Everton FC, Tranmere Rovers, Blackburn Rovers FC, Derby County FC, GB Cycling, Widnes RFL, Salford RFL, St Helens RFL and the Football Referees Association (**Sec.5, Source G**). As a consequence of undertaking more PPS activity some athletes have required follow-up investigations, however, there has been a relative reduction in the referral rate of athletes into secondary care from 10% to 4% primarily due the application of the new guidelines (**Sec.5, Source H**). This has reduced healthcare costs to the individual, club or organisation as well as reducing the unnecessary psychological and cost burden of false positive findings. In those with a true-positive PPS outcome

this has led to potential life-saving interventions/treatment in over 100 athletes. In 2020, members of the CHS group developed a protocol, 'The Somauroo Model', which provides guidance on cardiac considerations for 'return to play' in professional footballers during the Covid-19 pandemic. The application of this model allowed the CHS group, upon direct invite, to screen over 30 Premier and Football League Footballers from Liverpool FC, Wigan Athletic, Tranmere Rovers and Blackburn Rovers as part of their 'return to play' following contraction of the virus.

CHS staff were invited to develop and run a joint Sport Cardiology Clinic at Liverpool Heart and Chest Hospital. This clinic provides secondary care for athletes where further investigation is required following PPS. This clinic has supported 278 new and 314 follow-up patients, since its inception in 2018 (**Sec.5, Source H**). This initiative now provides complete cardiac care pathways for athletes within the North West region. Clinical decision-making and patient pathways are based on the research that underpins the guideline documents for diagnosis and management of cardiac conditions in athletes (**Sec.3, Ref 1-6; Sec.5, Source E**). CHS staff are expert members on the Cardiology Consensus Panel for the FA that has led to changes in PPS policy and education within the organisation. The development of patient pathways have drawn on CHS research (**Sec.3, Ref 1-6; Sec.5, Source E**) and have changed the management of football players with underlying cardiac conditions, that was previously lacking. Internationally, CHS staff have had a significant impact on large scale PPS provision in Qatar by undertaking PPS training and supporting PPS activity through 2 PhD studentships (**Sec.5, Source I**). In addition, we were invited to develop, launch and support an Athlete's Heart Centre (the first of its kind in Egypt) at the Wadi el Neel Hospital in Cairo based on research and policy documents from the CHS group. The Athletes Heart Centre has been established for 12 months and has undertaken PPS on 200 athletes (**Sec.5, Source J**).

5. Sources to corroborate the impact

- A. International Recommendations for ECG Interpretation in Athletes (Research informed guideline production)
- B. European Association of Preventive Cardiology (EAPC) and European Association of Cardiovascular Imaging (EACVI) joint position statement: recommendations for the indication and interpretation of cardiovascular imaging in the evaluation of the athlete's heart (Research informed guideline production)
- C. Pre-participation cardiovascular evaluation for athletic participants to prevent sudden death: Position paper from the EHRA and the EACPR, branches of the ESC. Endorsed by APHRS, HRS, and SOLAECE (Research informed guideline production)
- D. Pre-Participation Cardiac Screening (PPCS) Policy Document: Great Britain Cycling Team (GBCT) (Research informed policy document)
- E. 2020 ESC guidelines on sports cardiology and exercise in patients with cardiovascular disease (Research informed guideline production)
- F. A guideline update for the practice of echocardiography in the cardiac screening of sports participants: a joint policy statement from the British Society of Echocardiography and Cardiac Risk in the Young (Research informed policy document)
- G. Medical Officer for St Helens Rugby Football League Club (Audit and Testimonial)
- H. Clinical Lead for Outpatient Services at the Liverpool Heart and Chest Hospital (Testimonial)
- I. Research Manager, Aspetar Qatar Orthopaedic and Sports Medicine Hospital (The role of CHS staff and PPS and research / testimonial)
- J. Director, Wadi El Neel Hospital, Egypt (The role of CHS staff in development of the athlete heart centre / testimonial)