Institution:
Edge Hill University

Unit of Assessment:
26 – Sport and Exercise Sciences, Leisure and Tourism

Title of case study:
Changing practice in the consideration of fatigue as an aetiological factor for injury.

1. Summary of the impact

The impact of this research has been evident in a change of practice regarding the consideration of fatigue in musculoskeletal profiling, and as an aetiological risk factor for injury. This change in practice is evidenced across a range of user groups, influencing evidence-based practice in both the clinical and sporting context. The body of research has generated a shift in the consideration of fatigue with regards sporting injury incidence. Postgraduate teaching has evolved to consider injury prevention strategies in relation to fatigue, and Governing Body injury audits have cited this research in working toward injury prevention policies.

2. Underpinning research

The research underpinning this case study was undertaken by Greig. Greig joined Edge Hill University as a Lecturer in Sport and Exercise Biomechanics in April 2008. He has been employed continuously throughout the assessment period and is currently a Reader in Sport and Exercise Biomechanics in the Department of Sport and Physical Activity. The underpinning research was undertaken at Edge Hill between 2008 and 2010.

Injury audits by English and European football governing bodies have highlighted fatigue as a risk factor for injury in professional football. The interpretation is consistently a lack of physiological conditioning. This case study is based on a biomechanical consideration of fatigue as an aetiological risk factor.

Greig has developed a treadmill representation of the physical demands of match-play, showing that the mechanical response to soccer-specific exercise mirrors the epidemiological pattern of injury incidence. This exercise model has been used to conduct a series of studies investigating the influence of fatigue on biomechanical markers of injury.

Key Finding 1 (Output #1): Eccentric hamstring strength (as measured using isokinetic dynamometry) is impaired with soccer-specific fatigue, particularly at high speeds. The time history of changes in hamstring strength is in line with the incidence and mechanism of hamstring strain injury.

Key Finding 2 (Output #2): Acknowledging that isokinetic strength has limited kinesiological relation to soccer-specific activities, a kinematic analysis of agility sprinting was conducted using the same fatigue protocol. Agility, and in particular cutting, is both a high risk movement and functionally relevant to the observed changes in hamstring strength. A fatigue effect was evident in both knee flexion and varus, increasing the risk of injury.

The consideration of fatigue as a risk factor for injury was continued next by a PhD student (Small) supervised by Greig. This body of work further developed the exercise model of fatigue by creating a free-running protocol.

Key Finding 3 (Output #3): Acknowledging the limitations of treadmill protocols in replicating the functional activities inherent in soccer, a free-running protocol is presented which replicates the physical demands of match-play. Sprinting is a primary non-contact injury mechanism, and functionally related to hamstring strain injury which is a primary injury type. This study showed that fatigue induced technical changes in sprinting technique, with implications for injury.

Key Finding 4 (Output #4): The free-running protocol was shown to produce a similar magnitude decrease in eccentric hamstring strength as the treadmill protocol used previously. Again the changes in eccentric hamstring strength mirror epidemiological observations of injury incidence. The isokinetic dynamometry analysis was extended to consider functional changes in the strength-angle relationship, given the observed changes in running techniques. Fatigue was shown to influence both peak strength, and the angle of peak strength.

Research into fatigue as an aetiological factor for injury has continued, with Greig developing a body of work considering varied injury mechanisms. The consideration of fatigue has evolved from treadmill to free-running, and subsequently to repeated trials to reflect the impact of fixture congestion on the modern professional. PhD students currently supervised by Greig are investigating the physical response to soccer-specific exercise in the heat (as a precursor to World Cups in Rio and Qatar), and the development of injury prevention strategies to develop "fatigability". Injury epidemiology in similar intermittent team sports (supervised by Greig at M-Level) is being used to develop a research strategy considering whether a change in policy might be more effective than any musculo-skeletal intervention. Greig was recently asked to write a chapter entitled "Environmental factors for fatigue and injury in professional football" for the Routledge Handbook of Sport & Exercise.

3. References to the research

1. Journal Article: **Greig**, M. and Siegler, J. (2009). Soccer specific fatigue decreases eccentric hamstring strength. *Journal of Athletic Training*, 44(2), 180-184. (Output in REF2).
   ISI Web of Knowledge for Sport Sciences, Ranked 35th of 84 on Impact Factor = 1.68, 5 Yr IF = 3.11, Article Influence Score = 0.96 (Ranked in Top 10 for AIS), cited by 43

2. Journal Article: **Greig**, M.P. (2009). The influence of soccer-specific activity on the kinematics of an agility sprint. *European Journal of Sports Science*, 9(1), 23-33. (Output in REF2).
   ISI Web of Knowledge for Sport Sciences, Ranked 48 of 84 on Impact Factor = 1.15, 5 Yr IF = 1.34, Article Influence Score = 0.36; cited by 7

3. Journal Article: Small, K., McNaughton, L., **Greig**, M., Lohkamp, M. and Lovell, R. (2009). Soccer fatigue, sprinting and hamstring injury risk. *International Journal of Sports Medicine,* 30, 573-578. (Output in REF2).
   ISI Web of Knowledge for Sport Sciences, Ranked 18 of 84 on Impact Factor = 2.27, 5 Yr IF = 2.87, Article Influence Score = 0.55 (Ranked in Top 10 for Eigenfactor Score), cited by 25

4. Journal Article: Small, K., McNaughton, L., **Greig**, M. and Lovell, R. (2010). The effects of multidirectional soccer-specific fatigue on markers of hamstring injury risk. *Journal of Science & Medicine in Sport*, 13(1), 120-125. (Output in REF2).
   ISI Web of Knowledge for Sport Sciences, Ranked 10 of 84 on Impact Factor = 2.90, 5 Yr IF = 1.34, Article Influence Score = 0.85 (Ranked in Top 20 for Eigenfactor Score), cited by 46

5. Journal Article: Small, K., McNaughton, L., **Greig**, M. and Lovell, R. (2009). Effect of timing of eccentric hamstring strengthening exercises during soccer training: implications for muscle fatigability. *Journal of Strength and Conditioning Research,* 23(4), 1077-1083.
   doi: 10.1519/JSC.0b013e318194df5c
   ISI Web of Knowledge for Sport Sciences, Ranked 31 of 84 on Impact Factor = 1.80, 5 Yr IF = 2.27, Article Influence Score = 0.41 (Ranked in Top 10 for Eigenfactor Score) cited by 17

6. Journal Article: **Greig**, M., Johnson, C. and McNaughton, L. (2013). Environmental factors for fatigue and injury in professional football. In Y. Hong (Ed.) Routledge Handbook of Sport & Exercise.

4. Details of the impact

The following impacts arose between January 2008 and July 2013.

1) Changing practice by sports scientists and sports medicine practitioners in the consideration of fatigue as an aetiological risk factor for injury; highlighting the influence of fatigue on markers of injury, and in conducting musculoskeletal profiling and/or implementing injury prevention strategies post-exercise. Evidence-based-practice is paramount to practitioners across a number of user groups, to include sports scientists, physiotherapists, and medics. This change in practice has been evident in both clinical settings and professional football, as detailed below (KF 1-4).

Clinical Practice: Physiotherapists and medical practitioners have amended practice to acknowledge the influence of fatigue as an aetiological factor for injury. In 2013, Greig was invited by IPRS Mediquipe to deliver a key-note presentation entitled "Fatigue and isokinetics in football" to a delegation including clinicians, physiotherapists, sports scientists and practitioners from elite sport. Physiotherapists and clinicians were subsequently given the opportunity to discuss the practical implications of fatigue profiling with Greig and the distributors of the isokinetic dynamometer used in the research. Isokinetic profiles are typically conducted at rest. Greig's research has highlighted a 20% deficit post-fatigue, and clinically this magnitude of change would be "red-flagged" for intervention. Thus medical practitioners from private health institutions and elite sport have expanded the scope of isokinetic profiling to consider fatigue (Sources 1 and 2, Section 5). The most contemporary version of the isokinetic dynamometer, Biodex System 4, has recently been amended to add a fatigue component in the Biofeedback mode. This component has the ability to enable the clinician to select the desired percentage of fatigue (Source 1. Section 5).

Professional Football: Given the sport-specific focus of the research to date, the change in practice has been most evident in football. Over the last 6 years Greig has worked with the Football Association to provide sports science support to the development squads, primarily the U16 and U19 England teams. His research has influenced his own practice as a sports scientist. Players benefit from direct input in post-exercise prehabilitation programmes. As a sports scientist with the England squads Greig has worked with a physiotherapist, team Doctor, and coaching staff. These colleagues assist in the delivery of the interventions and are thereby also attaining new skills. Indirectly, through advisory groups and conference attendance, sports scientists at professional clubs are provided with professional development by the Football Association (Source 4, Section 5).

2) Injury prevention policy

This body of research undertaken by Greig considers the influence of fatigue as a biomechanical, rather than physiological, concern when evaluating injury risk and has been cited recently in the injury audit reports produced by UEFA (Risk Factors for Lower Extremity Muscle Injury in Professional Soccer: The UEFA Injury Study. *Am J Sports Med* 2013) and in contemporary reviews of injury prevention strategies (Hamstring Strain Injuries. *Sports Med* 2012*;* Hamstring injuries: are we heading in the right direction? *Br J Sports Med* 2012; Risk factors for hamstring muscle strain injury in sport: a systematic review and meta-analysis *Br J Sports Med 2013)*.

Working toward REF2020 this body of work is evolving to consider prehabilitation strategies and policy change driven by observations in other intermittent team sports. The cumulative impact of sport-specific exposure over a career in elite sport is also being investigated, with implications for the care and rehabilitation of retired players. In a follow-up of the UEFA

Champions League study, the impact of cumulative fatigue was considered in relation to fixture congestion (Source 5). The UEFA recommendation was to consider the design of match schedules to ensure recovery between games and minimise the impact of fatigue on injury. PhD work currently on-going under the supervision of Greig is considering the replication of tournament demands, using repeated bouts of the laboratory protocol.

5. Sources to corroborate the impact

Corroboration is provided by the following individuals:

1) Clinical Education Manager, Biodex (contactable) - to corroborate the change in medical systems to incorporate fatigue as a clinical factor when assessing and rehabilitating clients. The Biodex System 4 isokinetic dynamometer has been updated to include a software amendment which enables the practitioner to pre-select a desired level of fatigue.
2) Medical Practitioner, Harley St, Formerly of Chelsea FC (Factual Statement) - To corroborate the transferability of football-specific research into a sport and exercise setting, and further transcending sport into general medical practice.
3) Sports Physician at English Institute of Sport (Factual Statement) - To corroborate the impact of applied sports science research on medical practice in football, and across sports medicine practice more generally.
4) Head of Sports Science, The Football Association (Factual Statement) - To corroborate the involvement as a sports scientist with the FA, and the impact of this research on elite player development and coach education, and the evidence-based practice in football science.

Other Sources:

5) Bengtsson, H., Ekstrand, J., Hägglund, M. (2013). Muscle injury rates in professional football increase with fixture congestion: an 11-year follow-up of the UEFA Champions League injury study. *Br J Sports Med,* 47(12):743-7. doi: 10.1136/bjsports-2013-092383.