**BRINGING CUTTING EDGE RESEARCH INTO THE CLASSROOM: TEACHER NOTES**

**Technologies for computational analysis of sports and exercise**

The purpose of this document is to:

* Give an explanation of an advance of the research science for teachers including clear curriculum links
* Give guidance and access to sources of further information about advances in science for teachers and their students.

**Information about the Lead Researcher**:

Professor Iain Spears, Professor of Sport & Exercise University of Teesside

Professor Spears’ background is engineering, specialising in computational biomechanics in the areas of sport and exercise. Prior to sport and exercise, he worked in dental and orthopaedic research. (Further details about the researchers’ careers are given in separate documents.)

His orthopaedic research involved the development of a virtual-reality testing environment for non-cemented hip replacements. This work was the seminal stage of an EU-wide initiative for biomechanical data collection funded from the German Research Council.

Professor Spears' five current postgraduate students are developing technologies for analysis of the biomechanics of the musculoskeletal system. For example, his most recently successful MPhil and PhD students completed dissertations on the development of simulations of the ligamentous interactions of the ankle joint and the mechanics of repair of hip fracture patients, respectively.

Professor Spears led the EPSRC Digital Economy research project for a high-intensity low-volume exercise environment for use in social clubs.

One of Professor Spears’ current PhD students is Mark Wijnbergen.

Mark was a keen footballer at school and decided to pursue a career linked to sport. He achieved qualifications at MSc level in Human Movement Science and Sports Science and got his dream job at a top football club in his early 20s. There he developed an interest in research and has moved to the UK to study for a PhD at Teesside University. The working title of his PhD is “Development and evaluation of a performance analysis system for use in elite football” with builds on developments from work of Professor Spears and elsewhere. Mark acknowledges the different roles involved in developing performance monitoring and injury prevention programmes in elite sports: These include medical doctors, medical scientists, physiotherapists, human movement scientists, biomechanics researchers, computer programmers and sport scientists.

**Brief Overview of Research Focus for this resource**

In this research data is captured using various systems worn by the athlete and analysed to improve sport performance and prevent injuries.

**Biomechanics Research**

Most students will be familiar with games software which uses infra-red or accelerometers to detect player movements. In Professor Spears’ research markers are placed on an individual and movement videoed. Using weight data and force plates, the forces on the body can be calculated to assess injury risk to knees, calves, thighs, cruciate ligament etc. This also has application in design of artificial joints. Professor Iain Spears has recently developed a new system that can be used to screen athletes on the risk of sustaining different injuries, including sustaining an ACL rupture (described in the Student Information Sheets and below).

Replication of the research in the classroom will be achieved by viewing videos of a person jumping, and assessing the likelihood of injury against various criteria.

**GPS Monitoring of Sports Activities:**

GPS vests or chips in shirt are worn by, for example, football and rugby players during matches and the data collected can be used in a number of ways: to plot movement/distance travelled during the match, calculate velocity, maximum acceleration, make an estimate of calories used etc. Data has been provided by the researcher in an Excel spreadsheet and classroom activities could be based around analysis of this data. Articles are available about how well know sports teams have successfully used this technology (eg. <http://www.bbc.co.uk/news/business-36036742>).

Many students are likely be able to access apps (eg. “Runkeeper”, “Runtastic”) for smartphones (and/or low cost activity monitoring devices). These are less sophisticated that the research equipment but students will be able to monitor their own activities make comparisons to the research data provided. It should be noted that GPS data is used in sports research but currently it is not sufficiently detailed or accurate to be able to be used for injury prevention and analysis.

**Overview of the Links to the Curriculum**

**GCSE Science**

**Working Scientifically** including the following:

Science progresses through a cycle of hypothesis, practical experimentation, observation, theory development and review

Quantitative analysis is a central element both of many theories and of scientific methods of enquiry

The nature, processes and methods of science through different types of scientific enquiry that help to answer scientific questions about the world around them.

Application of observational, practical, modelling, enquiry, problem-solving skills and mathematical skills, in the laboratory, in the field and other environments.

Develop ability to evaluate claims based on science through critical analysis of the methodology, evidence and conclusions, both qualitatively and quantitatively.

Issues created by science – evaluating associated personal, social, economic and environmental implications.

Evaluating risks both in practical science and the wider societal context.

**Subject Content:**

Physics – Forces and Motion, Electromagnetic Waves

Biology – Co-ordination and Control

**A-Level**

Develop and demonstrate a deep appreciation of the skills, knowledge and understanding of scientific methods

Develop competence and confidence in a variety of practical, mathematical and problem solving skills,

Develop interest in and enthusiasm for the subject, including developing an interest in further study and careers associated with the subject

Understand how society makes decisions about scientific issues and how the sciences contribute to the success of the economy and society

Subject Content (Building on GCSE topics above plus):

Biology – Biodiversity, Control Systems

Physics – Vectors and scalars, Mechanics, Mechanical Properties of Matter, Waves

**RESEARCH BACKGROUND** **– Prevention of ACL Injury**

Anterior cruciate ligaments (ACL) are important in stabilising the knee joint and can be injured when overstretched. This tends to occur in sports where the athlete performs a “cutting” or twisting motion - 80% of all ACL rupture occurs during non-contact moments, especially during landings after a jump, or when decelerating while changing direction. These sports include football, rugby, basketball and alpine skiing.

An anterior cruciate ligament (ACL) rupture is one of the worst injuries an athlete can sustain. Some well-known sportsmen (Paul Gascoigne, Michael Owen, Tiger Woods, [Theo Walcott](http://www.telegraph.co.uk/sport/football/teams/arsenal/10669312/Im-learning-to-walk-again-says-Arsenals-Theo-Walcott.html) see also this [2015 newspaper article](http://www.telegraph.co.uk/sport/football/competitions/premier-league/11935356/Danny-Ings-becomes-latest-Premier-League-player-to-suffer-cruciate-ligament-injury-whats-causing-them.html) ) have suffered this injury. Often, when the ligament tears a popping sound is heard. Treatment can include reconstructive surgery and a recovery period of at least six months. Osteoarthritis can occur later. Adult female athletes have a 2-5 times higher risk of sustaining an ACL injury compared to adult male athletes – the adult female ACL tears at a lower loading force.

For further information about the ACL, click [here](https://www.youtube.com/watch?v=-3ZYNV0Py5E), for information about the role of the ACL in sports, click [here](https://www.youtube.com/watch?v=_4HJqBtlsEs).

An ACL rupture occurs when the applied load on the ligament exceeds the overall strength of the ligament. This exceeding load can occur when a shear force on the tibia is combined with internal-external rotation of the knee or valgus-varus moments (see Figure 1 and also the link to the [NHS article](http://www.nhs.uk/conditions/repairtotendon/Pages/Introduction.aspx) ).

After an athlete has sustained an ACL injury, a long rehabilitation program has to be followed. Normally, the athlete first has to undergo surgery to get an ACL reconstruction. For a short tutorial about an ACL reconstruction, click [here](https://www.youtube.com/watch?v=Xsq0sQp6DwU). Afterwards, a long rehabilitation program follows. Whereas it takes elite athletes on average 6-9 months to complete the rehabilitation, it takes other athletes often over a year before full recovery (even up to 3 years!). Another downside is the increased risk of an early onset of osteoarthritis in the knee.

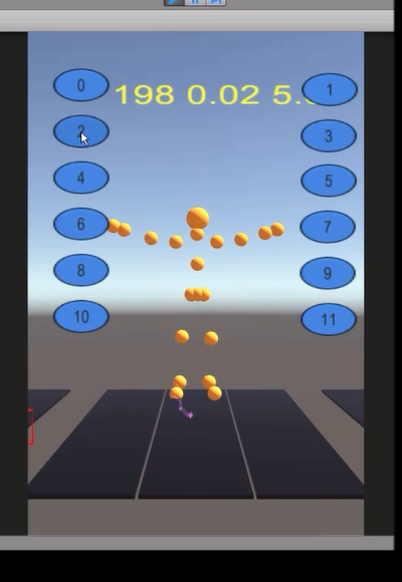


Figure 1. a) Normal stance (b) varus and (c) valgus stance of knee (torque force shown)

Prevention of this injury may be possible by training in movement technique. Screening tools can be used to identify candidates that might be susceptible to injury.

**Injury Screening Tools**

Therefore, several studies have been conducted to develop screening tools in order to select athletes that might benefit from additional training to prevent an ACL rupture. “Vicon” is a system that contains 6-8 infrared cameras which is often used to track the movement of the body. The cameras capture the markers that are placed on different position on the body (e.g. knee, femur, hip, and ankle). This can be used to calculate the different joint angles. Additionally, force plates are used to calculate the ground reaction force of the athletes during landing or running. With special software, the kinetic and kinematic variables of the athlete’s joints can be calculated. However, this is a very expensive system and therefore not usable in a lot of situations. As a solution to the high cost, a questionnaire (The Landing Error Score System, LESS) was developed that asks an observer to rate different movements (with a high risk of causing ACL rupture) of an athlete during a two-legged vertical drop jump. The score afterwards shows the risk an athlete has of sustaining an ACL rupture. However, a disadvantage with this questionnaire is that different observers can disagree on the score on different topics. Moreover, using this questionnaire is not very time efficient.

**Professor Iain Spears has recently developed a new system that can be used to screen athletes on the risk of sustaining different injuries, including sustaining an ACL rupture. During the screening, each athlete performs several tasks, like jumping with one, and with two legs. The system uses an infrared camera (WindowsTM Kinect) to capture the markers placed on different parts of the body of the athlete. It uses these markers to calculate the angles of different joints during each task. After every task, the program shows whether the athlete passed or failed this test.

*Useful References*

Articles about ACL injury

<http://www.nhs.uk/conditions/repairtotendon/Pages/Introduction.aspx>

[https://en.wikipedia.org/wiki/Anterior\_cruciate\_ligament\_injury accessed 9 March 2016](https://en.wikipedia.org/wiki/Anterior_cruciate_ligament_injury%20accessed%209%20March%202016)

Newspaper articles about ACL injury in footballers (many more available):

<http://www.telegraph.co.uk/sport/football/competitions/premier-league/11935356/Danny-Ings-becomes-latest-Premier-League-player-to-suffer-cruciate-ligament-injury-whats-causing-them.html>

<http://www.telegraph.co.uk/sport/football/teams/arsenal/10669312/Im-learning-to-walk-again-says-Arsenals-Theo-Walcott.html>

Youtube videos about ACL injury, training to prevent such an injury and type of jump used to evaluate technique:

<https://www.youtube.com/watch?v=dLXoA9d07WI>

<https://www.youtube.com/watch?v=Xsq0sQp6DwU>

<https://www.youtube.com/watch?v=-3ZYNV0Py5E>

<https://www.youtube.com/watch?v=_4HJqBtlsEs>

Example of a vertical drop jump:

<https://www.youtube.com/watch?v=Hv0FfX2PcjM>

Science Curriculum

GCSE: <https://www.gov.uk/government/publications/national-curriculum-in-england-science-programmes-of-study/national-curriculum-in-england-science-programmes-of-study#key-stage-4>

GCE AS and A Level: <https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/446829/A_level_science_subject_content.pdf>