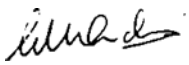
22/23

ANNUAL REVIEW

Sheffield Hallam University | Sports Engineering Research

Foreword

2022/23 has been another successful year for the Sports Engineering Research Group (SERG) – one of the four groups that collectively constitute the Sport and Physical Activity Research Centre (SPARC). Through its skilled and motivated staff, SERG has continued to deliver high-quality funded research projects for a broad range of external clients, strengthened its portfolio to include areas such as machine learning and digital health, and worked in partnership with teaching colleagues from the Academy of Sport and Physical Activity (ASPA) as well as staff from other departments in the University. Another high point for SERG this year has been its enhanced focus on student facing activity in ASPA, which has enabled genuine research-informed teaching to occur and added value to the student experience. Moreover, SERG has demonstrated its commitment to the University's 'civic' ambition through its targeted community focussed work. It is this type of rounded contribution that the Sport and Physical Activity (SPARC) aims to deliver and SERG's efforts are an excellent example of how this aspiration can be achieved.



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Introduction

The Sports Engineering Research Group (SERG) is part of the Sport and Physical Activity Research Centre (SPARC) at Sheffield Hallam University and is the world's largest academic group in sports engineering. We (SERG) are internationally renowned as a centre of excellence for research and knowledge transfer and our work is based on four research themes: sports analytics, biomechanics, design engineering and human morphology. In each area, our researchers develop fundamental knowledge and deliver applied solutions to enhance human performance, reduce injury and promote physical activity.

The core of SERG staff is co-located at Sheffield Hallam University's Advanced Wellbeing Research Centre (AWRC). As part of the Sheffield Olympic Legacy Park, the AWRC is a world-leading £15 million research centre dedicated to transforming lives through innovations that help people move. Funded by the Department of Health and Social Care, Sheffield Hallam University and with support by the European Regional Development Fund, the AWRC brings communities, businesses, clinical services and the public sector together with a range of academic expertise, including Sports Engineering, to prevent and treat chronic disease and tackle inequalities in society through world-leading research and innovation into physical activity.

The last academic year has been another busy one for SERG – delivering a wide range of high-quality research projects for new and existing clients, as well as providing an exciting environment for our students to learn. Over the last year we have grown as a research group. We have expanded into new areas, specifically around artificial intelligence (machine learning) and digital health. This has resulted in flourishing collaborations with departments from across the University, and we've also integrated research-active teaching colleagues from the Academy of Sport and Physical Activity into SERG.

We are proud of the long-standing research collaborations we have built up over the last 20 years with organisations such as UK Sports Institute, International Tennis Federation, FIFA and many other valued partners. Whilst these research programmes are mature and stable from an operational perspective, we constantly look for new and innovative solutions to real world challenges in the realms of both improving human performance and also sport/healthcare related equipment. A great example of this is our now licensed outdoor badminton shuttle, the Decathlon Perfly (licensed to Decathlon). This is a product of many years of research by the SERG team.

We are conscious of our responsibilities as a research group to enhance the student experience. We give unique opportunities to our students across the Academy of Sport and Physical Activity in the form of both research projects, placements and internships. We provide our students with challenging projects that give them the opportunity to learn new and applied skills that they can take into the workplace. For example, we have supervised Sport Science students on projects involving advanced data analytics and training machine learning models.

We fully support the University's commitment to the Civic University Agreement – delivering on activities and initiatives that engage and benefit the community. We provided a record number of work experience placements for local school children (Y10 and Y12) and delivered school lectures and interactive exhibits – exploiting our exciting field of research for supporting STEM. This demonstrates how our activity also aligns with one of the AWRC's key priorities – to collaborate with the local community and engage them in the co-design of products, interventions and services to help people move.

Dr Simon Goodwill, Head of Sports Engineering

Enhancing the student experience

SERG conduct a wide range of formal activities that allow students of all levels to engage with our research. In doing so we create authentic learning experiences, that are in line with the university strategic priorities of a truly applied curriculum.

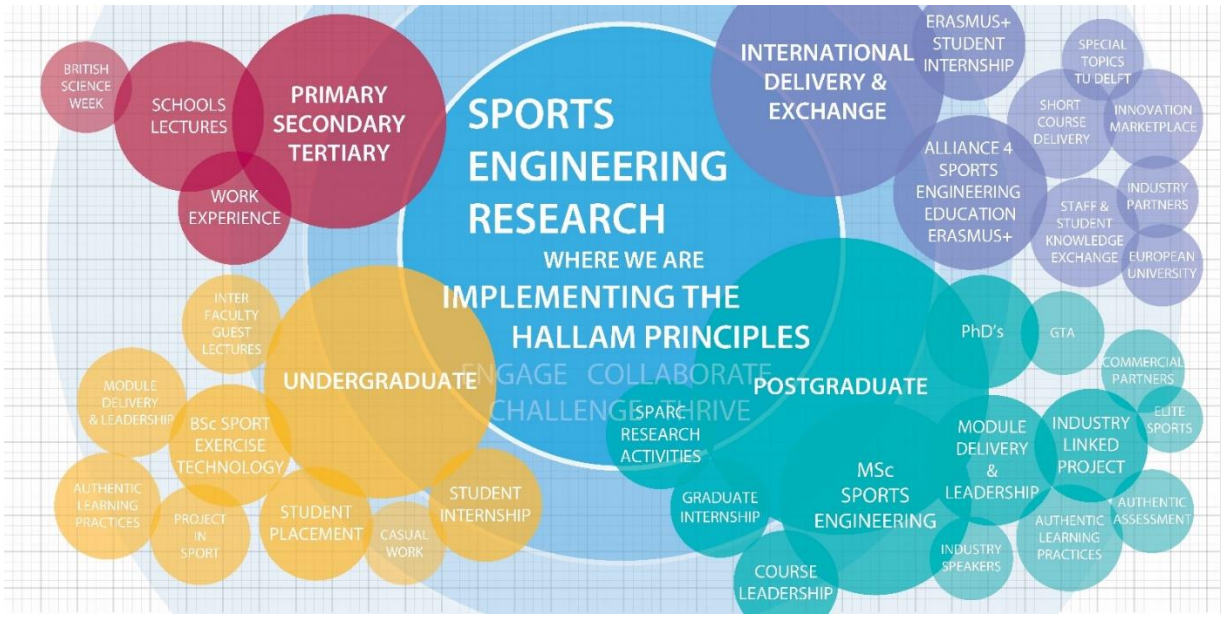


Figure 1: Activities and areas directly involving SERG staff, where the Hallam Principles are embedded into the student experience through engagement and involvement with our research and partnerships.

The benefits of embedding our research activity into the heart of the student experience not only benefits the student, but also directly benefits our research group, the wider university, and our local, national, and international collaborators. In doing so, SERG:

- Meets objectives set out in the SHU Civic University Agreement.
- Builds the strength and reputation of our research.
- Engages students at all levels with our cutting-edge research, in collaboration with our national and global partners.
- Facilitates and delivers international experiences through ERASMUS+ activities that create extracurricular opportunities where our students can thrive personally, culturally, and hone their entrepreneurial skills.
- Creates authentic learning and assessment experiences that prepare students for their future careers and helps inform career choice.
- Facilitates the forging of relationships between our students and industry that helps increase their employability.
- Develops high value graduates who can thrive professionally with skills that the market requires.
- Invests in the future of our research team through both SHU alumni and external recruitment.
- Brings in additional skills to the research team, providing flexible capacity in the group.
- Engages with the Hallam students of tomorrow through school outreach and experiential opportunities, and the postgraduate students of tomorrow through international delivery.

MSc Sports Engineering, and student placement opportunities

September 2022 saw the commencement of the 14th year of MSc Sports Engineering. The course which is developed and delivered almost exclusively by SERG staff, provides students with a truly authentic research-led learning experience. Realistic applied assessment is at the heart of the delivery and as ever students were challenged with real world problems throughout based on current research within the team, and input from our industrial clients. This year the team focused on developing a new version of this course, that is now fully validated and will launch in September 2024. The new delivery will embed real world client challenges at the heart of every assessment, further enhancing the learning and employability of our cohorts. This will be a unique programme that the teaching team are truly excited about.

Alongside developing a new course, the team have been busy delivering extracurricular international opportunities for the cohort alongside our A4SEE Erasmus+ colleagues. Students engaged in international mobility and COIL (Course Online International Learning) opportunities attending summer schools in Delft (NL) & Chemnitz (Ger) and travelling to Le Mans (Fr) and Vienna (Aus) as additions to the COIL activities.

Our work with elite sport has provided many opportunities for undergraduates to contribute to the success of Team GB. Level 5 placement students have been able to work on site with numerous teams including British Swimming and British Equestrian. Furthermore, they have had the opportunity to work alongside our many PhD researchers who are typically closer to them in age giving them an insight into a potential next step in their career pathway.

Level 6 and 7 students have conducted both physical and virtual research projects with a range of elite sports, including British Swimming. All these opportunities provide invaluable experience working with elite athletes and solving real-world challenges.

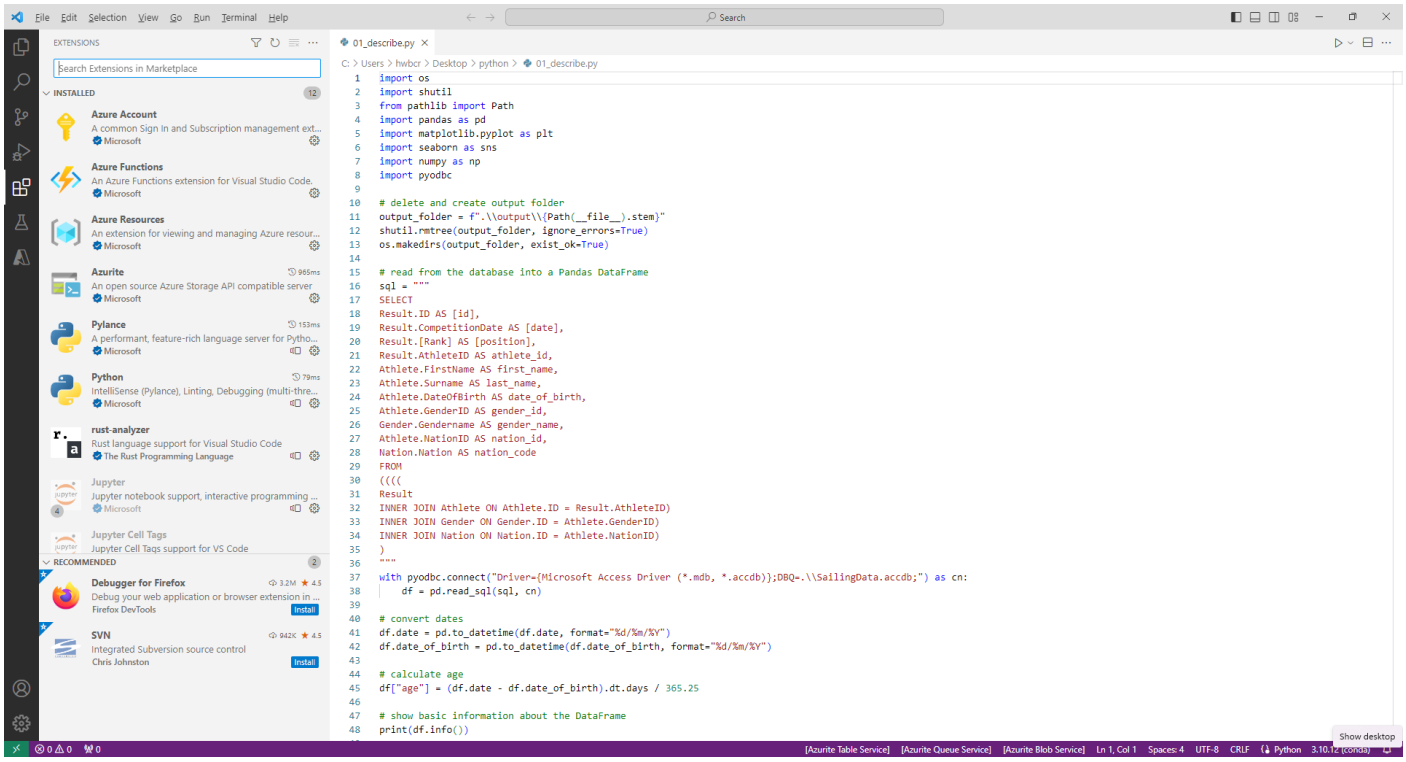


Figure 2: Example machine learning code created by the Level 5 BSc students during their internship.

A Level 5 BSc Sport and Business Management student had an internship experience that comprised two distinct components, each offering unique opportunities for learning and growth.

In the first part of the internship, the student was immersed in the world of sports analytics, specifically focused on one of SERG's new Olympic sport clients. SERG had been tasked with the development of a data system for this sport. The student contributed valuable insights and analysis to the client at no additional cost, thereby offering a symbiotic relationship. Simultaneously, this engagement provided the student with unparalleled experience, knowledge base and exposure.

The primary question from the client revolved around discerning whether disparities existed in the competitive experiences and exposure of athletes who succeeded versus those who did not. To address this question, a case study approach was adopted. The student's role involved data collection from various online sources and comprehensive one-on-one tutoring in tools such as Microsoft Excel, Microsoft Access, Microsoft Power BI, and Python. Additionally, the student designed a database and transferred data into it. To ensure the quality of the analysis, the student engaged in daily meetings with a member of the SERG team and had their work reviewed by another SERG analytical expert. Furthermore, the student was provided with custom computing hardware and software to facilitate these tasks. The finale of this work saw the student present findings to a director in the sport, which underscored the impact of their contributions.

In the second part of the internship, the student delved into cutting-edge technology by exploring the potential applications of OpenAI's ChatGPT. Tasked with investigating how this advanced technology could be harnessed to address the myriad of questions posed by Olympic coaches, practitioners, and leadership on a daily basis. The student leveraged their new-found programming skills in Python and the resources provided by Microsoft Azure. This phase of the internship not only broadened the student's technical expertise but also showcased the versatility of AI-driven solutions in the sports domain. The insights and findings the student gleaned from this exploration were shared with the UK Sports Institute, further underscoring the real-world impact of the student's work.

Another level 5 student is expected to do similar work in 2024. This will be the fifth student that has followed this path.

Industry Linked Projects

Alongside our projects with elite sport, our MSc students engage with our industrial partners. This allows students to undertake real world research on current issues. The continued projects we can offer each year is testament to the benefits our partners experience, as students bring capacity, enthusiasm, and knowledge, along with guidance and expertise from their supervisors.

A summary of our MSc projects this year is given in Table 1 below.

Table 1: Industry Linked Projects 2022-23

Project	Student	Industrial Partner
IMU assessment of bowling action	Vighnesh Hari	SERG
Considering friction between scalp and helmet, and how this may affect injury severity	Natasha Bialecki	SERG
Automatic detection of the taekwondo competition area	Faisal Bin Shahin	English Institute of Sports and GB Taekwondo
Tracking a golf ball on a Zen green stage	Lucas Schulz	PING Golf
Shuttle Structural Performance	Utpal Narvekar	SERG
Data analysis for injury prevention of taekwondo players	Amaldev Pulimthanathu Sreekumar	English Institute of Sports and GB Taekwondo
Measuring running dynamics using a Runscribe sensor	Michael Nott	On Running

A4SEE Alliance 4 Sports Engineering Education – ERASMUS+

As the A4SEE project approaches its final year, activity has increased significantly as the team makes up for opportunities originally lost during the pandemic. This year there were multiple opportunities for our MSc students to participate in extracurricular international collaboration and exchange. SERG staff again led the Innovation Marketplace a COIL activity that challenged students from across the collaboration to come up with innovative solutions to playing surface measurement and calibration. As part of this, teams enjoyed a field trip to Le Mans (France) in the October to visit our industrial partner Labosports European headquarters and lab facilities, even squeezing in a visit to the Le Mans 24 hr Museum. Students then returned to their home countries, were guided by SERG in weekly online sessions in the development of innovative solutions, before coming together again in the February to present at a final event held at ASTU-Wien in Vienna (Austria).

The SERG team are currently organising the final Innovation Marketplace that will involve German manufacturer Magura and include a field trip to their European headquarters. SERG staff were also involved in supporting the running of the Industry Collaboration Experience summer school in Chemnitz (Ger) and co-leading the Special Topics in Sports Engineering Course at TU Delft (NL).

Figure 3: Images from Innovation Marketplace visit to Labosport in Le Mans

Visit the Alliance for Sports Engineering Education's website (https://a4see.com/) to learn about their other activities and news about the project.

A4SEE Industry Collaboration Experience

Chemnitz – May 2023

The third Industry Collaboration Experience (ICE3) was a major success. Students, industry representatives, and academics travelled to Chemnitz University of Technology (TU Chemnitz) for a week-long intensive at the start of May 2023. The focus of the event was a collaboration opportunity resulting in meaningful and exciting outcomes for all who participated. This was a truly global event with representation from Germany, Austria, the Netherlands, Italy, Iran, Canada, Mexico, and the United Kingdom.

Figure 4: Images from Industry Collaboration Experience in Chemnitz

For students, this event presented the opportunity to apply technical knowledge gained from their university studies to work on real-world problems within a sports engineering context. Each project group comprised a mixture of students from 3 university partners (link to A4SEE partners' page: https://a4see.com/partners) providing the chance of working with a variety of people from across the world with diverse skills and backgrounds. The insights and knowledge gained through the hard work and dedication of the students provided the industry partners with useful insight for tackling current challenges within their respective companies.

The event was a fantastic success in maintaining existing and fostering new European collaboration opportunities. A very special thank you goes to the Department of Sports Equipment & Technology at TU Chemnitz for their warm welcome.

Special Topics in Sports Engineering, Delft – July 2023

The annual Special Topics in Sports Engineering course hosted at TU Delft was a real highlight of the academic year. One of SERG's interns, Loni Nickel wrote about her experiences of attending the 2023 edition of the course in an article for our *EngineeringSport* blog, extracts below:

"Organized through the Alliance for Sports Engineering Education (A4SEE), this course welcomes master's students in related MSc programs registered at one of the A4SEE partner universities. Each year, Delft University of Technology hosts this 2-week summer school in the beautiful city of Delft, Netherlands. For a lot of us students, it was our first time visiting

the country, and we all enjoyed exploring all that the Netherlands had to offer on the weekends and evenings. The many canals and historic buildings provided a wonderfully quaint backdrop for walking and cycling. It was very apparent that the Dutch love riding bikes and this mode of transport also became popular amongst my fellow students whilst travelling to and from the university"

Figure 5: Images from Special Topics Course in Delft

"Something I enjoyed about this course was meeting people from around the world who shared an interest in sports engineering. By the end of the week, we had all become very good friends and enjoyed getting to know each other and collaborating on projects. As a fellow teammate said, "The best part of the two weeks in Delft for me was the opportunity it provided to see and learn more about how people from different parts of the world approach a problem. Since the groups represented good demographic variation among members, it was interesting to work with people who have come from different educational upbringings."

See the full post written by Loni on her experiences in Delft on the Sports Engineering blog here - https://engineeringsport.co.uk/2023/09/15/special-topics-in-sports-engineering-2023-a-students-perspective/

Graduate Internships and paid casual researchers

In SERG, our people are our most valuable resource, and we recognise the importance of investing in them. Through our *BSc Sport & Exercise Technology* and *MSc Sports Engineering* courses, plus our PhD research programmes, we educate many fantastic students and want to harness this talent during and after their studies. We offer many different opportunities including:

- PhD students being able to work on contract research projects outside of their own research.
- Graduating students to work on short term funded projects when they graduate, to give them a bridging position before they secure a long-term position.
- International students completing both paid and study-related internships.

During these roles, the students are given the chance to increase their employability and research skills, by working with senior researchers on funded projects.

Kunal Gaikwad and Arun Joy - Artificial Intelligence, Sheffield Hallam University

In July 2023, SERG employed two L7 MSc Artificial Intelligence students, Kunal Gaikwad and Arun Joy, for a 3-month internship to train machine learning models for athlete movement analysis. Kunal and Arun have carried out a comparative analysis of open-source pose estimation and segmentation models trained for British Swimming. The state-of-the-art models accurately identify the swimmer's body parts and joint angles which help in analysing their take-off performance (Fig a and b). This work has provided these students with the opportunity to develop technical and professional experience working with real-world data from British Swimming alongside the SERG team, and this research has given SERG the foundation to respond to funding calls in this area. They gave this view on their time with us:

"We had a great experience working with current projects. We were able to stabilise point tracking within the video data successfully. There are a few areas left to improve, but we look forward to developing those in future."

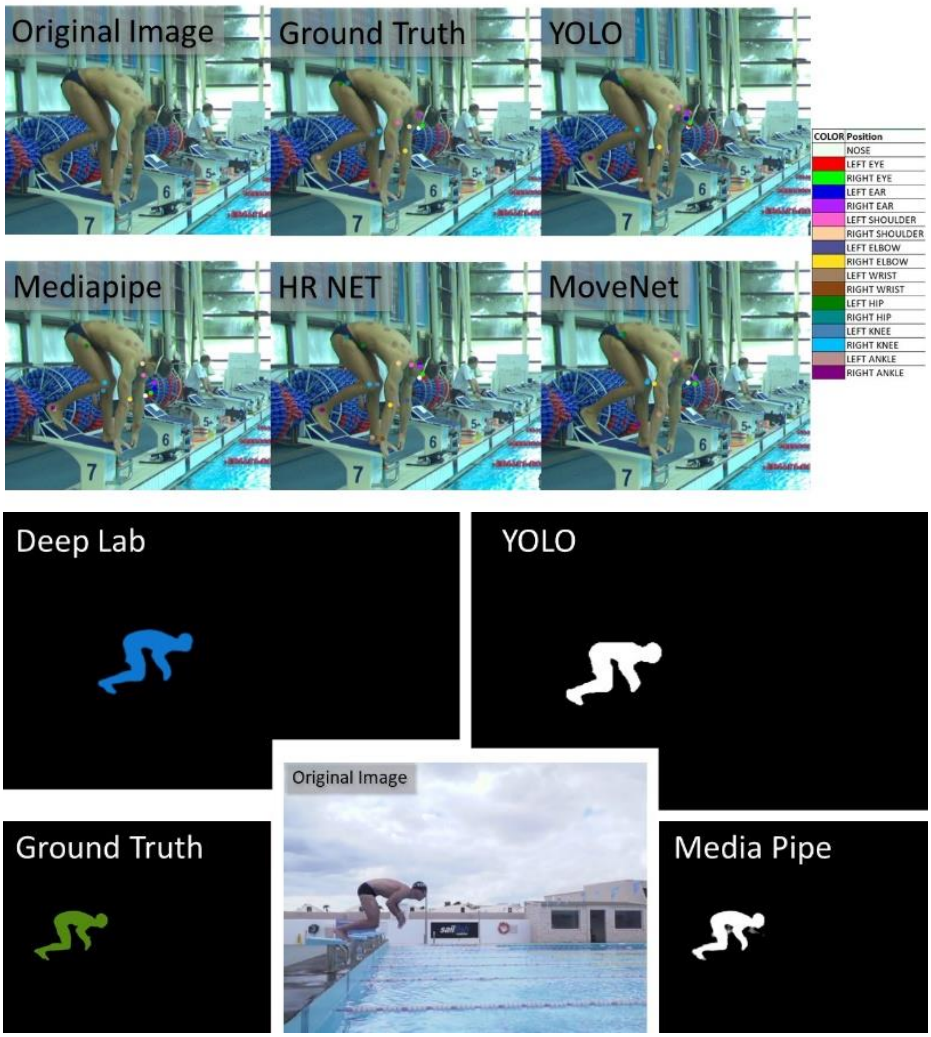


Figure 6: i) Pose estimation model comparison on British Swimming dataset ii) Performance comparison of segmentation models.

Loni Nickel – Mechanical Engineering, University of Alberta

Loni Nickel, a Mechanical Engineering Co-op student from the University of Alberta, Canada, completed a 9-month research internship at the AWRC with SERG in 2023. Loni had an action-packed internship, getting involved in a range of research projects, conducting off-site testing and travelling to three different countries as part of the A4SEE collaboration, taking part in community engagement activities, as well as presenting her research findings at an international conference! Further details of these are as follows:

- Research projects
  - A reliability study for a drop-test method to assess ice-hockey helmets against concussion-based impacts.
  - A study to quantify how the static and dynamic properties of footballs are affected by internal air pressure.
  - A study assessing wearable sensors in football and their effectiveness at recording head impact events.

Figure 7: Photos from the research projects

- **International work-related travel**
  - Innovation Marketplace in Vienna, Austria
  - Industry Collaborative Experience (ICE3) in Chemnitz, Germany
  - Special Topics in Sports Engineering Summer School in Delft, Netherlands

- **Community engagement**
  - Loni actively contributed to school events and presentations like "This Girl Can," where she had the opportunity to engage kids in games and physical activities to explain how we can measure human movement through heart rate monitors, motion detection, and speed gates.

- **International conference presentation**
  - Loni presented findings from her work on the ice-hockey helmets concussive impacts reliability study at the ADM 2023 conference in Florence, Italy.

Figure 8: Images taken during Loni's research internship with SERG.

Loni gave this view on her time with us:

"These past 9 months have been filled with many incredible experiences and impactful projects. I was very lucky to have been allowed to explore my interests within the field of sports engineering and gain valuable knowledge and a skill base that I can take with me as I progress in my academic studies and future career."

"Being able to work on real-world problems within sports engineering enforced my passion for this field of work. This experience has opened my eyes to all the many possibilities for research within this field. I learned about and was able to contribute to the inspiring projects that are currently being tackled by the Sports Engineering Research Group while witnessing their impact on the many communities involved in sports."

Areli Rabner Concha – Biomedical Engineering, Universidad Iberoamericana, Mexico City

Areli Rabner Concha was a biomedical engineering undergraduate student from Universidad Iberoamericana in Mexico City, who joined SERG as an intern for 6 months from January until July 2023. Areli's research contributed towards the AGE4A Powered Assistive Exercise project, specifically she investigated novel methods for measuring flexibility in older adults, as part of which she recruited 25 people and measured their flexibility whilst performing a range of movements. Areli's study led to intense competition for the coveted "Most flexible member of SERG" award! After her project Areli returned to Mexico to graduate and is now working for a company producing radiology equipment.

Figure 9: i) Crash test dummy instrumented with motion capture sensors ii) Areli instrumented during an experiment iii) Areli outside the AWRC

Recent SERG PhD student successes

Award for Daniel Haid at the Sportfortec 2022 Conference

Congratulations to Daniel Haid, one of SERGs PhD students, for winning 'Best Presentation' at the Sportfortec 2022 Conference held at Chemnitz University. During the final year of his PhD, Daniel has also presented his PhD research at the International Conference on Mechanical MetaMaterials in Manchester, the Associazione Nazionale Disegno E Metodi (ADM) International conference in Florence and the International Research Council on the Biomechanics of Injury (IRCOBI) conference in Cambridge. Daniel is now at the point of submitting his PhD thesis for examination and has started a new role as a KTP associate with Cellbond ATD and Loughborough University.

Figure 10: Photo of Dan receiving award at the Sportfortec event in Chemnitz.

Presentation by Cavan Aulton at the European Conference on Sport Science

SERG PhD student Cavan Aulton gave a presentation on "How we can optimise the use of Machine Learning and Computer Vision in sport" at the European Conference on Sport Science in July 2023.

His research focuses on optimizing the use of machine learning and computer vision in sports. The presentation was based on an opinion piece that is currently under review for publication, focused on how an ecological framework, grounded in ecological dynamics and the Department of Methodology, can support practitioners seeking to integrate machine learning and computer vision technologies into athlete development programmes.

"Overall ECSS 2023 was a great experience as it was my first conference and my first time presenting my research to an external audience and served as a great opportunity to meet new people from both the computer and sport science world."

Figure 11: Cavan presenting at ECSS Paris 2023

First paper for Katie Mills from FIFA sponsored PhD Scholarship

Congratulations go to Katie Mills, one of SERGs PhD students, who recently published a paper entitled "Repeatability of a piezoelectric force platform to measure impact metrics for a single model of football" from her research with FIFA. Katie's paper can be accessed at https://link.springer.com/article/10.1007/s12283-022-00389-y. Katie's PhD scholarship is the first that FIFA has directly funded, and has been developed to provide an excellent, industry-focussed training experience. Katie has also presented her work at FIFA's Research Symposium, as well as an international academic conference, and has developed a great network as a result.

SERG has worked with FIFA since 2014, beginning with validation of goal line technology systems in situ. Since then, SERG and FIFA have developed safety standards for GPS tracking devices, assessing the accuracy of virtual offside line technologies, the precision of instrumented footballs (to be used in the world cup), and even improving the repeatability of FIFAs quality assurance procedures.

Figure 12: FIFA Quality Programme Conference and FIFA Research Symposium

The SERG team are passionate and dedicated to our field of research that combines engineering, technology, sport and healthcare. Our research is firmly placed inside the broader STEM collection and can be used as a platform to enthuse children and adults (young and old). We recognise that we can provide fantastic opportunities to engage the public and teach them skills that will enable them to succeed in this increasingly complex, technological world. The Sports Engineering field allows these skills to be taught in a sporting context which often engages students who would previously have not embraced this field of academia.

Work Experience

Figure 13: Images Taken During the Work Experience Events

We recognise that we are in a position to be able to provide transformational work experience to school children, and we gladly embrace this responsibility. This year SERG welcomed a record seven students from different schools across South Yorkshire and embedded them within our research group. We invest time in these students at the start of the placement – coordinating team building exercises and other skills training. For the rest of their time, they are getting first-hand experience of the research we conduct and the athletes/clients we work with. Amongst the specific highlights this year was unrestricted access to the GB Boxing training facility and seeing the athletes in preparations for Paris 2024. During this visit, they got to meet various practitioners who support the athletes. These included a performance analyst, a physiotherapist, a sports nutritionist and a data analyst. They were fascinated to learn that they could combine their love of sport with their ability in a more academic subject. These kinds of unique opportunities are only available because of the close relationships we build with our research partners over many years of collaboration.

This Girl Can

Every June during the city's annual Move More Month, a three-day community sport event takes place at the Sheffield Olympic Legacy Park, delivered by the National Centre for Sport and Exercise Medicine. The event offers Sheffield schools and communities an opportunity to take part in a wide range of sports and activities, focusing on mass participation and school sport. We work with our four School Sport Partnerships in Sheffield: Links, Forge, Arches and Points each year to deliver two events that run simultaneously: the This Girl Can event and a Colour Smash.

The *This Girl Can* campaign celebrates active women who are doing their thing no matter how they look, how well they do it or how sweaty they get. It empowers women and girls of all shapes, sizes and sporting abilities by showing them that there is no 'right' way to get active. SERG were invited to participate in a showcase event hosted by Ice Sheffield and English Institute of Sheffield. Year 9 and 10 girls from schools across Sheffield took part in different activities with the overall aim being to promote physical activity in lots of different guises.

SERG created a series of exciting public engagement activities that demonstrated how technology can be used to both measure and promote physical activity. Combining expertise from across the Sports and Physical Activity Research Centre (SPARC) and exploiting our close collaborations with the Computer Science department, we promoted both physical activity (explaining the health benefits) and the importance of STEM subjects through exciting, engaging and fun filled activities.

We related all our exhibits to our real-world research. For example, we demonstrated how our pose estimation research with GB Taekwondo can be translated to measure how much someone moves when dancing.

Figure 14: Images Taken at the This Girl Can Event

See Sheffield Hallam's recent blog post about this year's event at [https://www.shu.ac.uk/about-us/our-role-in-the-region/civic-university-agreement/civic-blog/this-girl-can.](https://www.shu.ac.uk/about-us/our-role-in-the-region/civic-university-agreement/civic-blog/this-girl-can)

UTC Challenge

The UTC Sheffield Olympic Legacy Park is a purpose-built specialist academy/sixth form located next to the AWRC. This year the AWRC, alongside SERG, set students the challenge of 'How to use technology to increase physical activity levels locally". The students worked in groups to develop a business pitch of up to 3 minutes for £50,000 of funding to help increase physical activity levels of 13- to 19-year-olds in and around Darnall. The pitch had to consider what technology they would use; how the chosen technology could be used to promote more daily movement; why the technology would appeal to young people; and how they would assess if the technology increased physical activity levels. The winning team were awarded the chance an experience day in the Morphology Lab at the AWRC, using our range of 3D body scanners to create a rapid prototyped figurine.

Figure 15: Image of UTC Challenge competition winners

The UTC Challenge is just one example of how SERG is contributing to Sheffield Hallam's Civic University Agreement, working closely with partners to deliver benefits across South Yorkshire and the city region. Integrating our research and innovation initiatives with local health services and working with community groups in the Darnall and Attercliffe areas, we hope to help tackle health inequalities and address health challenges.

British Science Week

British Science Week is a weeklong celebration of science, technology, engineering and maths, which this year took place from 10 to 19 March 2023. Science Week is part of the Science Summer School national initiative co-founded in 2012 by Professor Brian Cox CBE and Lord Andrew Mawson OBE, with the aim of making the UK the best place in the world to do science and engineering.

SERG was one of 12 local organisations, delivering workshops and inspiring speeches to develop awareness of science, technology, engineering, arts and maths (STEAM) subjects and employment opportunities for young people within the local region in response to the growing need for professionals in these industries.

This year the event saw students from schools across Sheffield come to the AWRC, where they were introduced to the world of sports engineering and possible careers within the field. The pupils were given an insight into the world of working in sports engineering, as well as the incredible career paths that brought the speakers and presenters to where they are today.

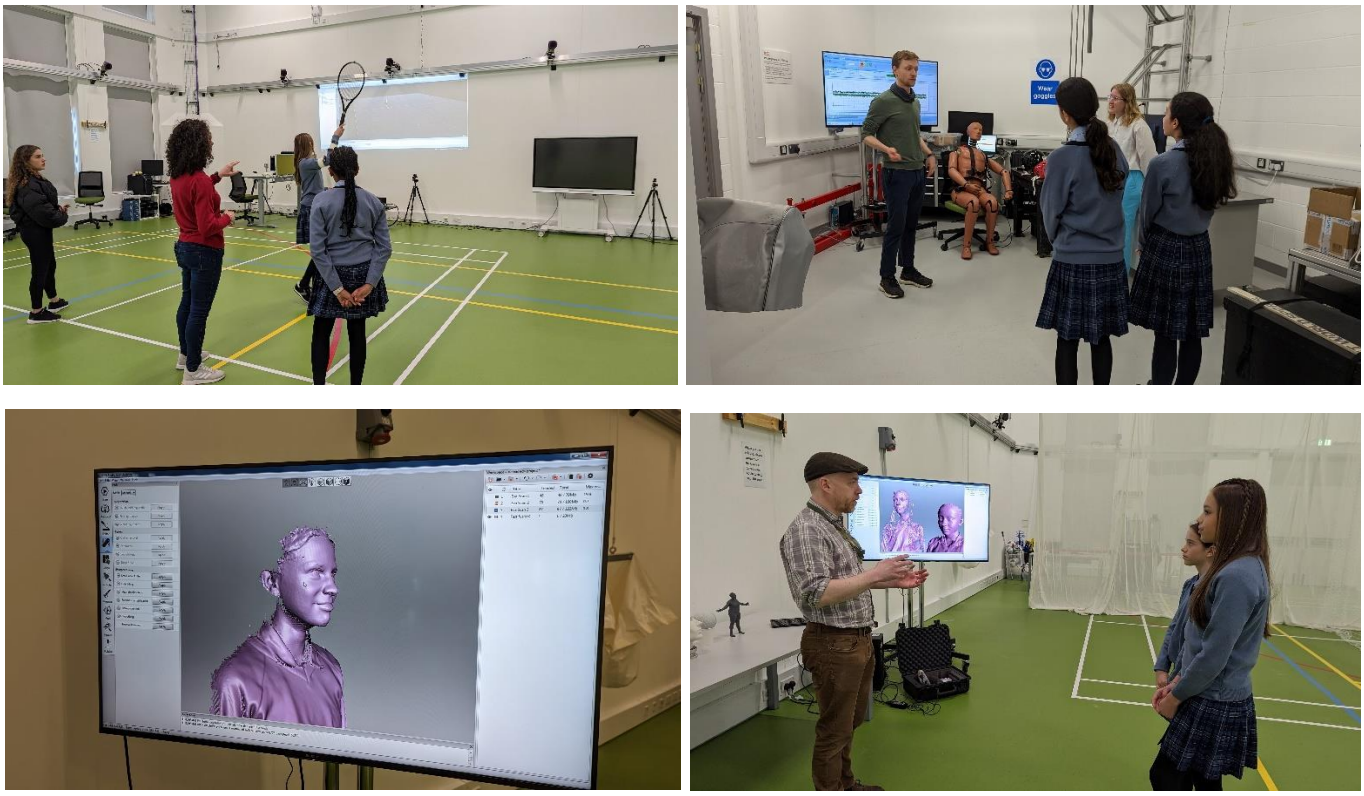


Figure 16: Images of Science Week activities at the AWRC

Biomechanics

Biomechanics is the application of the principles of physics to human movement. It plays an important role in both health care and sports settings, as it can help people move without pain, reduce injury risk, and enhance athletic performance.

At SERG we have a state-of-the-art biomechanics laboratory within the AWRC, equipped with a 24-camera motion capture system and 6 force platforms. The large capture volume and the multiple force platform allow the measurement of a variety of activities and the possibility to analyse multiple successive steps and record data from two feet at the same time.

Our team works with external partners and companies both in the sports and health care sectors in biomechanics areas that can be grouped as follows:

- **Sports biomechanics**: analysis of athlete movement to enhance performance and reduce injury risk in different sports, such as football, tennis, running, cycling, and golf.
- **Athlete-surface interaction**: analysis of the effects of footwear and sports surfaces on athlete movement. Projects in this area include work with major artificial turf and footwear manufacturers.
- **Athlete-equipment interaction**: analysis of athletic performance related to changes at the point of interaction between athlete and equipment (e.g. grip, insole) or changes in sports equipment design or set-up.
- **Validation of easy-to-use measurement systems**: we use the AWRC gold-standard laboratory facilities to validate novel low-cost easy-to-use technologies (wearables) designed for field-based measurements. Such systems include textile-based sensors, low-cost camera systems and inertial measurement units.
- **Biomechanics of rehabilitation**: assessment of new approaches to rehabilitation through our measurement systems.
- **Balance measurement and restoration**: measurement of static and dynamic balance in sporting and rehabilitation contexts, using force platform, sensor-based approaches and gamification.
- **Movement variability**: this new field of study offers promising insights into movement control with the potential to improve performance and reduce injury risk in sport, occupational and rehabilitation applications.

One of the main current focuses of our biomechanics team at SERG is to move biomechanical measurements from laboratory settings to the field. A recently awarded year-long Early Career Research Fellowship to a member of our team will help further development in this area. In-field measurements allow the analysis of movement in representative environments, where participants can adjust their movements, take decisions in response to realistic external stimuli, and are not restricted to a limited testing area. We use the facilities available at the AWRC to compare different measurement systems and help the development of easy-to-use wearable technologies that can help the population to independently improve balance and gait, to reduce injury and enhance performance. We apply an ecological dynamics approach to the data generated by wearable technologies to analyse complex human movements and their variability, and to understand the individual-environment relationship.

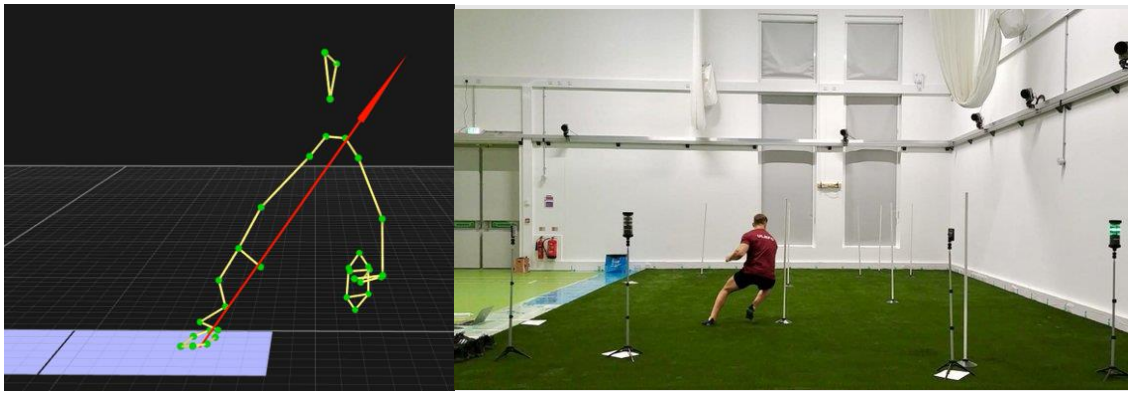


Figure 17: Football boot traction study utilising the AWRC 500 m² movement analysis laboratory, including force plates and 26 camera Qualisys system

Recent publications

Jongerius, N., Wainwright, B., Wheat, J., Bissas, A. (2021). Prevalence and functional implications of Soleus and Tibialis anterior activation strategies during cycling. Journal of Sports Sciences.

Rowley, L.J., Churchill, S.M., Dunn, M., Wheat, J. (2021). Effect of hurdling step strategy on the kinematics of the hurdle clearance technique. Sports Biomechanics.

Rowley, L.J., Churchill, S.M., Dunn, M., Wheat, J. (2021). Effect of hurdling step strategy on the kinematics of the block start. Sports Biomechanics.

Sconce, E., Heller, B., Maden-Wilkinson, T., Hamilton, N (2021) Development of a novel Nordic hamstring exercise device to measure and modify the knee flexors' torque-length relationship. Frontiers in Sport and Active Living

Burnie, L., Barratt, P., Davids, K., Worsfold, P., Wheat, J (2020). Biomechanical measures of short-term maximal cycling on an ergometer: a test-retest study. Sports Biomechanics, 1-19.

Choppin, S., Clarkson, S., Bullas, A., Thelwell, M., Heller, B., & Wheat, J. (2020). Anatomical and principal axes are not aligned in the torso: considerations for users of geometric modelling methods. Journal of Biomechanics, 110151.

Dunn, M., Davies, D., Hart, J. (2020). Effect of Football Size and Mass in Youth Football Head Impacts. Proceedings, 49 (1), e29.

Dunn, M., Chiu, C-Y., Kelley, J., Haake, S. (2020). Technologies to Aid Public Understanding in Running Performance. Proceedings, 49 (1), e26.

Judson, L.J., Churchill, S., Barnes, A., Stone, J., Wheat, J. (2020). Joint moments and power in the acceleration phase of bend sprinting. Journal of Biomechanics, p. 109632.

Quirk, H., Heller, B., Wright, N. (2020). Feasibility and acceptability of physical activity monitoring as an educational tool in the management of paediatric type 1 diabetes. Canadian Journal of Diabetes 44(8):688-696 31

Morphology Research and Advanced Human Measurement

The morphology research theme explores the impact and value of body measures to performance, training and health, with a specialism in 3D surface imaging. We want to change current practice regarding individual and population-level human measurement. The Morphology laboratory at the AWRC is home to our morphology and advanced human measurement research. The laboratory contains equipment that can measure external shape and internal body composition including:

- Sizestream SS20 full-body scanner
- BodPod air displacement plethysmograph
- 3DMD torso high resolution scanner
- Artec Eva & Spider handheld scanners

and affords us access to the MR facilities and Medical Diagnostic Centre at the Canon Medical Arena – through the AWRC partnership with Canon Medical and relationship with Living Care.

Our research priorities include:

1. **Relationships between advanced methods of measurement (such as shape) and health, in adults and children** (Lead: Dr Alice Bullas/Dr Michael Thelwell): Our primary tool of investigation is a unique shape analysis tool developed by Dr Michael Thelwell during his PhD. With our shape analysis techniques, we can extract much more meaningful information compared to traditional tools such as tape measures and callipers. We can apply these techniques to any 3D scan of a human body to assess its specific shape and size, for example within Jamie Allan (Student LTU / SHU) doctoral studies in *'Shape analysis of the human foot using three-dimensional foot scanning*'.
2. **The suitability and acceptability of body measurement methods and measures** (Lead: Dr Alice Bullas/Dr Michael Thelwell).
3. **Identify the most accurate and suitable external body size measures to assess factors causally associated with obesity** (Lead: Dr Alice Bullas).
4. **Chemotherapy dosage and body surface area** (Lead: Dr Michael Thelwell): As part of an early career fellowship, Dr Michael Thelwell will be investigating how advanced body measurement techniques can be utilised to improve the accuracy of determining body surface area for use in prescribing cytotoxic chemotherapy dosage within anti-cancer treatment.
5. **Cost-effective 3D human reconstruction techniques for sports and health analysis** (Lead: Dr Chuang-Yuan Chiu): Developing single-camera-based approaches for generating individual 3D human models for measuring human performance in the fields, including body composition, strength, and conditioning.
6. **3D imaging for design, modelling and simulation** (Dr John Hart): We use a range of imaging solutions to create 3D models suitable for use in design analysis, and simulation. This allows us to build a detailed understanding of specific equipment performance, or to develop bespoke design solutions for an individual.
7. **Application of 3D imaging to art & theatre** (Lead: Dr John Hart / Dr Alice Bullas).

   To maximise research quality, integrity and impact we actively contribute to, and benefit from, a broad understanding of the field and network - locally, regionally, national and globally, including:
   - Sheffield Multimodal Imaging Centre (SMIC)
   - Yorkshire Obesity Research Alliance (YORA)
   - International Society for the Advancement of Kinanthropometry (ISAK)
   - British, European and Global standards committees and working groups

Figure 18: Human measurement equipment in the AWRC morphology laboratory

CASE STUDY: Integrating 3D imaging into theatre

Beck Gadsby, Founder of Inside Theatre and Sheffield-based Theatre Director and Producer, has a passion for experimenting with innovative digital technology for the future of performance. As the director of 5 Years, a new play written by Hayley Davis, Beck sought our 3D imaging and modelling expertise. This was used to create an animated model to explore the play's theme of the perfect body, and what people would do to achieve it.

3D imaging experts from our Sports Engineering Research Group, Dr John Hart and Dr Alice Bullas, scanned and generated digital 3D and miniature physical models of both actors in the play. The 3D model of the lead actor was then animated by Games Art Course Lecturer and Character Design Specialist, Jamie Gibson.

Figure 19: Images provided by Mark Turner

The animated 3D and miniature physical models are now integrated into the 5 years play, set to tour around the UK in 2023. This work has demonstrated the potential, wide, interdisciplinary impact of our imaging technology in Sports Engineering, from the arts and theatre to ergonomics, fashion or design. The research, in combination with our Sheffield Multimodal Imaging Centre and the strategic partnership between Canon Medical and the Advanced Wellbeing Research Centre provides the perfect opportunity for body imaging research and consultancy.

"By using this technology, we were able to demonstrate the concept of the piece - what do we lose in the pursuit of perfection - in a more tangible and visual way. It has been very well received by audiences who have said it is like a third actor on stage."

Beck Gadsby, Director, 5 years

This work was funded through the European Regional Development Fund: Digital Innovation for Growth (DIfG).

Recent publications

Bullas, A., Choppin, S., Heller, B., & Wheat, J. (2022). *Comparison of Complex and Simple Anthropometrics in the Descriptive Anthropometric Assessment of Male Cyclists*. *International Journal of Kinanthropometry, 2 (2), 13-27. http://doi.org/10.34256/ijk2222*

Bullas, A.M., Greenwood, R., Thelwell, M., & Choppin, S. (2022). *A review of commercially available 3D surface imaging systems for body composition estimation*. *Applied Sciences, 12 (17). http://doi.org/10.3390/app12178815*

Choppin, S., Bullas, A., & Thelwell, M. (2022). *Torso shape improves the prediction of body fat magnitude and distribution*. *International Journal of Environmental Research and Public Health, 19 (14). http://doi.org/10.3390/ijerph19148302*

Chiu, C.-.Y., Dunn, M., Heller, B., Churchill, S., & Maden-Wilkinson, T. (2022). *Modification and refinement of three-dimensional reconstruction to estimate body volume from a simulated single-camera image*. *Obesity Science and Practice. http://doi.org/10.1002/osp4.627*

Thelwell, M., Bullas, A., Kühnapfel, A., Hart, J., Ahnert, P., Wheat, J., ... Choppin, S. (2022). *Modelling of human torso shape variation inferred by geometric morphometrics*. *PLOS ONE, 17 (3). http://doi.org/10.1371/journal.pone.0265255*

Design Engineering

To improve product performance our researchers, aim to develop a better understanding of sports equipment and its interface to users and the environment. We research whether something is possible and develop engineering solutions to fulfil product needs using fundamental physics, experimental methods and modelling techniques. We utilise user-centred design to push the boundaries of innovation in sports equipment and validate our interventions using advanced measurement systems. We have a focus on injury prevention and improving sports product performance.

By understanding the causality of injury, we physically replicate and computationally simulate representative scenarios to mitigate the impact. Through this work we have helped to develop products, evolve materials and set new test standards. The workshops and labs at the AWRC house a range of our test equipment including a drop-rigs, Instron quasi-static and dynamic test machines, impact simulators, ball projectors and crash test dummies. We augment these with a range of measurement systems including high speed video, Tekscan and inertial measurement units.

We offer a wide range of expertise in the design of sports equipment from concept through prototyping, testing to production. We can support product development with computational simulation, CFD and FEA, and analysis of product performance through physical testing. At the AWRC we have a wide range of test equipment and the ability to develop bespoke test rigs when required. We have an extensive range of prototyping equipment and skills to enable design iterations to be tested by users and their performance assessed.

Case Study: Drop test rig to replicate head impact scenarios in ice hockey

Ice hockey has one of the highest concussion rates in sports and ~90% of reported concussions in ice hockey are the result of collisions with other players. Collision type impacts, that can produce high strains in the brain, are characterised by lower accelerations and higher impact durations than falls onto the ice, although only falls onto the ice are represented in certification standards. Helmet evaluations in peer-reviewed literature require a variety of laboratory equipment. A simplified test protocol, based on impacts which commonly cause concussion, could facilitate representative helmet testing by more researchers, while increasing the feasibility of modifications to certification standards.

A 50th percentile male Hybrid III crash-test dummy headform was fitted with IMUS and tested with four different ice hockey helmets, with typical materials and technologies. Linear acceleration and angular velocity were measured during impacts onto different surfaces at different angles using a free-fall drop test. Video footage was recorded to explain some impact events and measure impact velocity. Drops were carried out from a height of 1m on to a representative range of locations resulting in an impact velocity of 4.5m/s, similar to standard procedures and common test protocols in literature, resulting in an impact energy of 51.3 – 53.8 J. Impact duration and peak linear and angular acceleration were used as measures of helmet performance.

The highest accelerations and shortest impact durations were produced during impacts onto rigid surfaces. With increasing impact surface compliance, the peak accelerations decreased while impact durations increased. A broad range of headform kinematic responses during impact was obtained, changing with impact surface compliance and surface orientation. The relative difference in kinematic values between helmeted and non-helmeted impacts decreased with increasing impact surface compliance, agreeing with previous work. The linear and angular accelerations were similar to the characteristic kinematic responses of ice hockey head impacts. These findings suggest that the free-fall drop test method can replicate collision type head impacts in ice hockey.

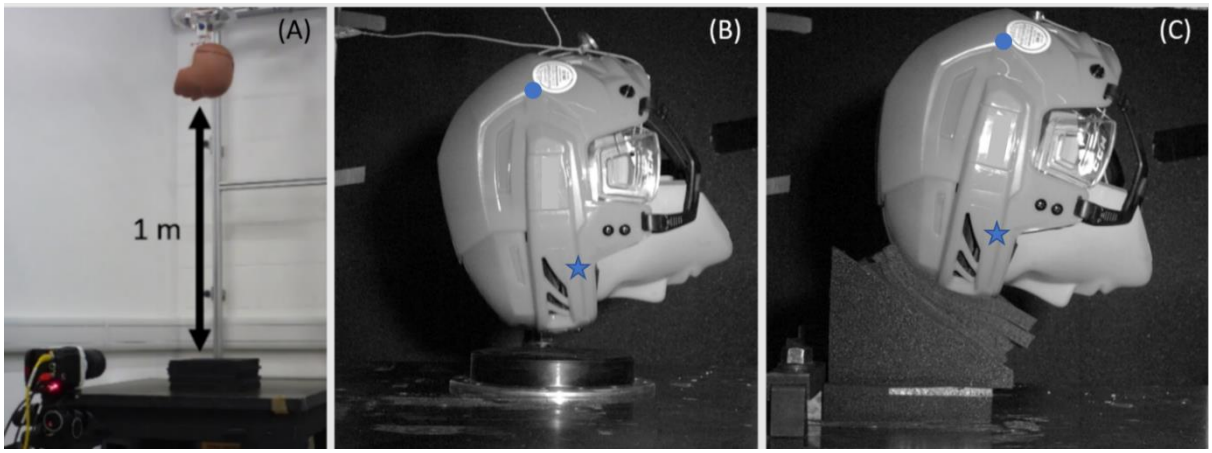


Figure 20: (A) Free-fall drop test setup, (B) Front site, flat MEP pad surface just before impact (C) Front site, oblique 72 mm foam during impact with FrontBoss («) and RearBoss (●) impact sites marked.

Recent publications

Gemma E. Leslie, Keith Winwood, Weizhuo Wang, Nick Hamilton, Tom Allen (2023). Effect of limb surrogate surface compliance on the impact response of wrist protectors, JSAMS Plus

Alaster Yoxall, Alison Tingle, John Hart, Jen Rowson, Inna Lucas, Jennie Wilson. (2023) "Fancy a Brew? ": Understanding factors influencing ease of use of cups used in care homes. Clinical Nutrition Open Science

Nicholas B. Tiller, Louise A. Turner, John Hart, Richard Casaburi. (2021). Airflow dynamics and exhaled-breath temperature following cold-water ingestion. Respiratory Physiology & Neurobiology.

Daniel Haid, Leon Foster, John Hart, Richard Greenwald, Tom Allen, Pooya Sareh, Olly Duncan. (2023) Mechanical metamaterials for sports helmets: structural mechanics, design optimisation, and performance. Smart Materials and Structures

Daniel Haid, Oliver Duncan, John Hart, Leon Foster (2023). Free-fall drop test with interchangeable surfaces to recreate concussive ice hockey head impacts. Sports Engineering.

Katie L. Mills, Johsan Billingham, Simon Choppin, Marcus Dunn, Terry Senior & Simon Goodwill. (2022) Repeatability of a piezoelectric force platform to measure impact metrics for a single model of football. Sports Engineering.

Sports Analytics

Sports analytics involves both the collection and analysis of sports data. This is often with the goal of gaining a performance edge. It can also be to improve the way governing bodies mange and protect their sport. The aims of the sports analytics group are to develop and apply novel data collection solutions and bespoke data analysis methods.

Data collection

SERG have designed and built several novel data collection solutions. The research partnership with UK Sports Institute works with many Team GB sports to provide bespoke performance data collection and management solutions. Our methods and solutions involve mobile apps, local and Azure cloud databases, image processing, camera technologies and sensor devices. Data collection is often in challenging training or competition environments, such as the *SwimTrack* system for British Swimming. *SwimTrack* incorporates four underwater cameras and six above water cameras feeding directly into software running on a poolside PC to provide kinetic and kinematic data. The data collection is typically from multiple sources - *SwimTrack* is one of four data collections systems produced by SHU for British swimming (*Nemo*, *Kraken* and *Triton*) and the data from these systems are linked with data from more than 5 other data sources collated via another SHU developed system, *Linking*. Other projects demonstrating this level of novel and wide-reaching data collection include the Boccia *SmartCourts* system.

Data analysis

Dr. Chaung-Yuan Chiu analysed data gathered from the SERG bespoke software, providing profound insights for sports video analysis and injury prevention. Deep learning models were created to automatically detect the GB Taekwondo competition area. By integrating advanced image processing techniques, reference vertex points were established to ascertain camera localization during capturing, enabling a detailed understanding of player movement during competitions. Furthermore, multiple machine learning models will help to predict fatigue and muscle soreness among elite athletes. This aids coaches in adjusting training loads, mitigating injury risks, and enhancing training effectiveness.

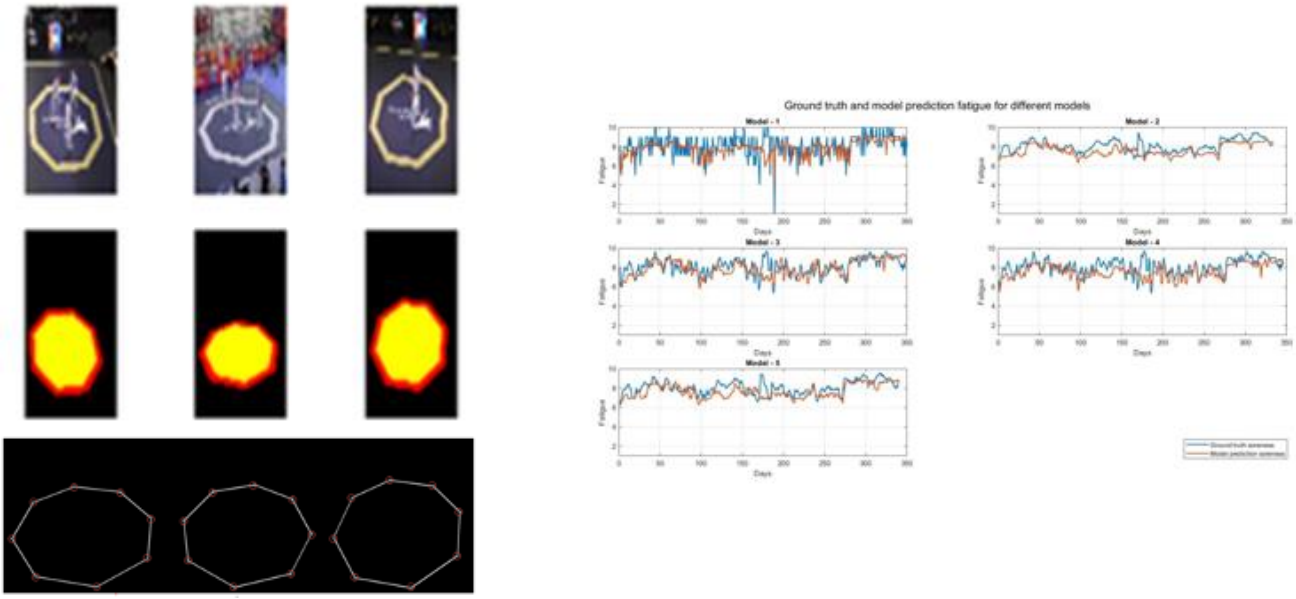


Figure 21: i) Deep learning models to determine competition areas in taekwondo; ii) machine learning models to predict fatigue and muscle soreness.

Rankings and ratings

SERG use competition modelling to answer research questions on rating and ranking methods. One project of our research partnership with the International Tennis Federation (ITF) focussed on designing the ranking methods used for the Davis Cup and Billie Jean King Cup. A model of both competitions was created and used to design and compare multiple different ranking algorithms. Since the Covid Pandemic, such modelling and testing has been required to inform decisions made by the ITF to maintain the integrity of the competition and the rankings as ties have been cancelled or postponed. SERG have also applied similar methods to Olympic sports as part of the UKSI research partnership.

Applied Performance Analysis

Access to new larger-scale data sets of requires the creation of novel performance metrics. A PhD funded by Sheffield Hallam University and the Lawn Tennis Association was the first to analyse Wimbledon's own data set. Completed by Dr Anna Fitzpatrick and entitled Imp*ortant Performance Characteristics in Elite Grass Court Tennis: Implications for Practice*, the programme of research developed a new performance metric – PWOL. This metric was used to identify which Tennis performance characteristics are most associated with success, and which are not.

Forecasting

In addition to creating new performance metrics, SERG has experience using large-scale datasets to predict future performances, such as medal-winning times at the Olympic and Paralympic Games. Such knowledge is vital for sports to optimise athlete and event selection. Our forecasting approach uses Bayesian analysis techniques to generate probability distributions for the future events we predict. This approach is more advantageous for the sporting domain, where the outcome is never certain.

Contract Research Projects

UK Sports Institute Research Partnership:

- iBoxer – developed for GB Boxing to store a range of data sets including tournament results, videos, attendance, weight, and wellness in a single data store.
- SwimTrack – a kinetic and kinematic analysis developed for British Swimming.
- SmartCourts – A data collection and storage system for Boccia.
- myTKD – A data management system for GB Taekwondo that provides a single location for all datasets which allows the sport to combine and correlate information from different areasSI002 SHU funded research.
- NEMO – a race data collection and management system which is used to quantify race performance in swimming.
- Kraken – a data system that collects and stores rankings and competition results for British Para Swimming
- British Swimming Results Database – a system to obtain and store comprehensive list of swimming results.
- Swimming Linking System – a system that joins all British Swimming's data stores.
- Superbowl – a system to collect training and match data using a mobile device app and store the data in a cloud database.
- Predicting medal winning times in para-swimming.

International Tennis Federation Research Partnership:

- TennisNET – the collection and storage of ball testing results for ITF ball approval.
- TennisGUT – a tennis ball, racket, and surface simulator.
- SPRite cannon – A court surface testing deviceITF019 - HawkeyeITF023 - Davis Cup rankings.
- Davis Cup rankings – Designing the world ranking system for the Davis Cup.
- Fed Cup rankings – Designing the world ranking system for the Billie Jean King Cup.

Recent publications

- Hext, A., Hettinga, F.J., & McInerney, C. (2023). *Tactical positioning behaviours in short-track speed skating: A static and dynamic sequence analysis*. *Journal of Sports Sciences*. *http://doi.org/10.1080/02640414.2023.2238162*
- Hext, A., Hettinga, F., & McInerney, C. (2022). *Tactical positioning in short-track speed skating: The utility of race-specific athlete-opponent interactions*. *European Journal of Sport Science*. *http://doi.org/10.1080/17461391.2022.2069513*
- Fitzpatrick, A., Stone, J., Choppin, S., & Kelley, J. (2021). *Investigating the most important aspect of grass court tennis: short points*. *International Journal of Sports Science and Coaching*. *http://doi.org/10.1177/1747954121999593*
- Fitzpatrick, A., Stone, J., Choppin, S., & Kelley, J. (2019). *Important performance characteristics in elite clay and grass court tennis match-play*. *International Journal of Performance Analysis in Sport*. *http://doi.org/10.1080/24748668.2019.1685804*
- Fitzpatrick, A., Stone, J., Choppin, S., & Kelley, J. (2019). *A simple new method for identifying performance characteristics associated with success in elite tennis. International Journal of Sports Science & Coaching, 14 (1), 43-50. http://doi.org/10.1177/1747954118809089*
- Driscoll, H., Hudson, C., Dunn, M., & Kelley, J. (2018). *Image based stroke-rate detection system for swim race analysis*. *Proceedings, 2 (6), 286-292. http://doi.org/10.3390/proceedings2060286*

Dr Alice Bullas is a Research Fellow in advanced human measurement, specialising in the body measurement of elite athletes, exploring the impact and value of body measures to performance and training, with a specialism in 3D surface imaging.

Alice delivers on an array of sports and health research and innovation projects, alongside active involvement in anthropometry research, peer review, international standards development and working groups, and education; supervising several PhD students and teaching on the MSc in Sports Engineering and BSc in Sports and Exercise Science courses.

Skills: 3D imaging, body measurement, kinanthropometry, sport & health innovation.

Dr Chuang-Yuan Chiu is a Research Fellow specialising in kinanthropometry and applied computing, particularly in computer vision and machine learning. He is currently leading several industrial consultancy projects in this field.

He devised artificial intelligence applications for advanced data collection and analysis in sports and health. He also develops cost-efficient volumetric scanning methods to understand body shapes and poses from consumable devices. This has led to anthropometric and biomechanical research with international partners in the US and Australia.

Skills: Data analytics, 3D body and equipment scanning, computer vision, machine learning.

Associate Professor Simon Choppin is leader of the Morphology research group and works on new methods of measuring the human body, for the purposes of health and performance assessment.

His research interests also include physical system modelling, computer vision and high-speed video. In addition to working with many international companies in the sport and health domains, Simon has taught on the MSc in Sports Engineering for over 10 years. He leads the industry linked project module, where students have the opportunity at working on live projects linked to a sporting company. He is a passionate advocate for PhD research and student development and was one of the first UK Council of Graduate Education's accredited PhD supervisors in the country.

Skills: Data analytics, 3D imaging, camera technologies, image processing.

David Curtis is a Principal Research Fellow. Areas of practice and research interest are innovation programmes for sport and wellbeing; remote monitoring use of outdoor spaces; the mechanics of swung implements in sport; and application of the Cynefin framework to sport and innovation complexity scenarios to improve decision making.

David has been responsible for developing and managing large collaborative projects such as the EU ProFit Fieldlab project, the Sheffield city region sports cluster initiative SportsPulse, and AWRC-Westfield Health research programme. He also teaches sport undergraduates on enterprise & innovation at level 5 and 6 and is the sport science subject group operations lead.

Skills: sport & wellbeing innovation, research design, information governance, impact mechanics, horizon scanning.

Dr Francesca D'Andrea is a Researcher in the Sports Engineering Research Group specialised in biomechanics, in-field measurement of human movement and wearable technologies.

Francesca is currently involved in several research projects looking to improve and develop easy-to-use wearable systems able to move biomechanical measurement outside the laboratory both in the health and sports sectors. These systems can help the population to independently improve balance and gait, to reduce injury and enhance performance.

Skills: Wearable sensors, biomechanics

Dr Marcus Dunn is a Research Fellow specialising in the development of applied measurement systems to advance human movement assessment in representative and real-world settings.

Marcus works with international sports governing bodies, international sports companies, and healthcare specialists, to create bespoke measurement and feedback solutions. His research addresses human movement and impact dynamics, to advance understanding of injury, performance, and rehabilitation. Finally, Marcus developed three applied measurement science modules for BSc Sport and Exercise Technology (level six lead), leads the MSc Sports Engineering module 'Applied Measurement in Sports Engineering', and supervises five PhD students (UK and Australian institutions).

Skills: Image processing, biomechanics, camera technologies, 2D and 3D imaging systems

Dr Leon Foster is a Senior Research Fellow specialising in the design and development of performance analysis systems. Leon has developed bespoke hardware and software solutions for performance analysis tools used by elite GB athletes as well as the public.

Leon has a keen interest in testing sports equipment and develops testing protocols to evaluate the safety of protective sporting equipment.

In addition to his research, Leon lectures within the MSc Sports Engineering course and supervises several PhD students.

Skills: Camera technologies, database design, wearable sensors and bespoke electronics, materials testing and instrumentation, impact mechanics.

Dr Simon Goodwill is a Principal Research Fellow and Head of the Sports Engineering Research Group.

He leads the EIS Innovation Partnership project and has developed a wide range of systems to help monitor elite athlete's training and tournament performances. Simon has over 15 years of software programming experience and has built applications that interface with a variety of hardware devices including machine vision cameras, timing units, force platforms and IP cameras.

Simon's main research area is in the application of novel photogrammetry techniques.

Skills: Software development, camera technologies, database design, wellness monitoring

Professor Steve Haake is a Professor of Sports Engineering and the Director of Engagement at the Advanced Wellbeing Research Centre at Sheffield Hallam University. Steve was the founder of the discipline of sports engineering, has edited 9 books and contributed to over 220 journal and conference papers. He is a member of the Technical Commission of the International Tennis Federation, the EIS Technical Steering Group, and chairs both the parkrun Research Board and Sheffield City Region's Active Travel Board.

He has extensive media experience, writing a book called Advantage Play: Technologies that changed Sporting History, writing for the New Scientist and appearing on Radio 4's The Life Scientific. He was awarded an OBE in the Queen's Honours List in 2020 for services to sport and education.

Skills: Data analytics, impact mechanics, business development, popular science media.

Nick Hamilton is a Principal Research Fellow specialising in the design, innovation, analysis and manufacture of sports products. He has developed a wide variety of products for a diverse range of sporting companies from ice skates to carbon fibre time trial bikes, golf clubs to hang glider components.

He has a specialism in injury prevention applying a range of experimental and analytical techniques to understand and mitigate the causality of injury. Nick also works to increase physical activity levels of the population through the design of engaging outdoor spaces.

In addition to his research, Nick leads the SERG Design Engineering research theme and is vice chair of the Outdoor recreation research group.

Skills: Human Centred design, injury prevention, impact mechanics, design engineering, rapid prototyping, materials testing.

Dr John Hart is a Senior Research Fellow. He is an expert in Computational Fluid Dynamics (CFD), reverse engineering and 3D imaging. John works within the sports and healthcare sectors. This has included product development for Badminton England (Sport England Innovation Fund), Sheffield Teaching Hospitals (Abbeyfield Research Foundation) and aerodynamic analysis for Ping Golf, work which led to the G30 driver, a #1 selling driver in Europe and USA.

John leads the MSc in Sports Engineering and teaches on the Erasmus+ A4SEE funded programme.

Skills: Fluid and structural simulation, design engineering and rapid prototyping, 3D body and equipment scanning.

Associate Professor Ben Heller is an expert in medical engineering and instrumentation, particularly for the ambulatory monitoring of human activity.

Current research areas include ambulatory monitoring of physical activity, the motivation of exercise for older people through technology, ecologically valid measurement and rehabilitation of balance, characterisation of running biomechanics and advanced functional electrical stimulation approaches in neural rehabilitation.

Skills: Wearable sensors and bespoke electronics, wellness, biomechanics.

Dr Andy Hext is a Researcher in the Sports Engineering Research Group specialising in sports performance analysis. He delivers data projects for the English Institute of Sport, the International Tennis Federation, and the Sheffield Innovation Programme.

Andy is currently completing a year-long Early Career Fellowship on data analytics in elite sport and health & wellbeing.

Skills: Data analysis, sports performance analysis, image processing

Dr Chris Hudson is a Senior Research Fellow specialising in the development of data management and data analysis systems for Olympic and Paralympic sports.

Chris works within the EIS Innovation Partnership project and has developed a wide range of systems that collect, store, analyse, and report sports performance data. Over the last 10 years' Chris has been embedded within multiple Olympic sports - understanding the key priorities of the practitioners and the fundamental requirements of the analysis system. He works with the practitioners to co-design the required system, and through rapid prototyping and iterating of the solution, Chris consistently delivers world leading solutions for Team GB.

Skills: Software development, database design.

Dr John Kelley is a Research Fellow specialising in sports performance analysis, software development and data solutions.

John has worked with the International Tennis Federation, creating their world ranking systems for the Davis Cup and the Billie Jean King Cup as well as contributing to their equipment testing laboratory, creating bespoke image analysis software tools. John also works with a wide range of British Olympic and Paralympic teams creating bespoke data and video management systems designed for effective performance analysis.

In addition to his research, John leads the MSc Numerical Programming in Sports Engineering module.

Skills: Software development, camera technologies, mobile app development, image processing, cloud database solutions, MATLAB

Mahaa Irshad is a Computer Scientist (Research Fellow) with experience working in various domains of AI; prediction modelling, reinforcement learning, computer vision, and deep learning. Her recent experience includes developing prediction model for optimization of water consumption in golf courses.

She completed a master's degree in Intelligent Systems and Robotics from the University of Essex (UoE). Her dissertation focused on the development of self-learning-based game playing agent using reinforcement and deep learning.

She has worked with the Brain Computer Interface and Neural Engineering (BCI-NE) research group at UoE, developing classification models for limb and arithmetic calculations using brain signals captured with magnetoencephalography. Mahaa has an extensive research background of 4 years working on MEMS accelerometers and mechatronic system designing.

Skills: Computer vision, Mechatronics system design, Sensor technology, Artificial Intelligence, Reinforcement Learning, Deep Learning

Terry Senior is a Principal Research Fellow who is responsible for the design, build and evaluation of all products created by Sports Engineering and now the AWRC.

Over the last 3 years, Terry has worked closely with academics from across the University, taking responsibility for ensuring that the AWRC has the appropriate research equipment and infrastructure to deliver its vision.

Terry contributes to a wide range of consultancy and research projects within the department, is a PhD supervisor, coordinates the MSc laboratory activities, manages the department laboratory and is the department's health and safety officer.

Skills: Design engineering and rapid prototyping, impact mechanics, materials testing

Dr Michael Thelwell is a Research Fellow in advanced human body measurement techniques and 3D surface-imaging for assessing physical health.

His research focuses on the development of advanced body measures using 3D imaging, to provide improved tools for characterising variations in external human body shape and its relationship with underlying fat mass distribution and associated cardio-metabolic health risks.

He is currently completing an Early Career Research and Innovation Fellowship, investigating how advanced measures can be utilised within cancer treatment, specifically the assessment of cancer-related cachexia and improving the accuracy of body measures used in chemotherapy dose prescription He has continued to develop his academic profile as an expert within his field and is a reviewer for several academic journals.

He teaches on BSc and MSc modules in biomechanics, advanced measurement techniques and human factors across the Sport and Exercise Science and Sports Engineering degree programmes, as well as supervising 2 PhD students.

Skills: 3D body and equipment scanning, human body measurement, data analytics.

Associate Researchers

Dr Andy Barnes
Senior Lecturer in Sport and Exercise Science

Dr Sarah Churchill
Senior Lecturer

Professor Rob Copeland
Director of The Advanced Wellbeing Research Centre, Professor of Physical Activity and Health

Professor Keith Davids
Professor of Motor Learning

Tom Maden-Wilkinson
Senior Research Fellow

Dr Gabriella Penitente
Senior Lecturer in Sport and Exercise Biomechanics

Dr Jonathan Potts
Senior Lecturer and Course Leader of the BSc (Hons) Product Design Engineering

Dr Mohsen Shafizadeh
Senior Lecturer in Human Movement Science

Dr Joe Stone
Senior Lecturer in Performance Analysis and Skill Acquisition

Professor Jon Wheat
Associate Dean, Research and Innovation, College of Health, Wellbeing and Life Sciences

Research students

Our current PhD students with the title of their research project.

Jamie Allan

Shape analysis of the human foot using three-dimensional foot scanning: implications for the design of footwear and foot orthoses

Cavan Aulton

Improving skill acquisition with machine learning technologies

Shaun Barratt

Player location and event detection for combat sport using computer vision

Charlotte Benkowitz

The impact of parkrun on the health and wellbeing of the Australian population and lessons for other interventions

Will Dawber

Developing an Improved Methodology for the Assessment of Public Order Helmet Efficacy

Allison Dunne

Community-based physical activity and mental wellbeing; a case study of parkrun

Daniel Epifano

The Effect of Head Impact Exposure on Brain Health and Movement Adaptability

Daniel Haid

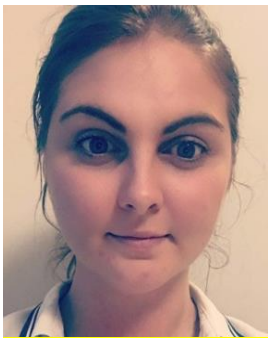
Effect of established and novel helmet liner characteristics during impacts with compliant bodies

Adam Kennerley

Objective movement analysis to inform safe return to sport in young people

Katie Mills

The dynamic interaction between a football and surface in match play



Charlotte Pedley

What forces are acting on the paediatric shoulder through normal development stages and what effect do these forces have on the development of the shoulder?

Lee Rowley

The Effect of Step Strategy on the Clearance of the First Hurdle

Emma Sconce

A device to modify the torque-length relationship of the knee flexors

Daniel Williams

Biomechanical adaptations to changes in bicycle set-up in elite athletes

Visiting researchers

Professor David James is the Managing Director of Labosport Ltd and holds a title of Visiting Professor at Sheffield Hallam University.

Labosport is a large multinational sports engineering consultancy and test laboratory dedicated to sports surfaces, infrastructure and equipment. David was a former researcher and subsequently the Director of SERG. He has been working in the field of sports engineering for 20 years and has sustained a significant contribution to research and knowledge transfer through a myriad of projects with sports companies and federations. David works with SERG on several collaborative teaching and research projects such as the Erasmus+ A4SEE programme.

Garry Owen is a Performance Data Analyst at GB Taekwondo and visiting researcher with SERG.

A qualified and accredited performance analyst with a MSc in Performance Analysis from the University of Chester, Garry has worked across a multitude of sports ranging from Olympic Sports to professional football. He moved into elite sport for the last two Olympic Cycles working with GB Boxing, British Cycling, GB Taekwondo and as a Technical Lead. Now directly supporting GB Taekwondo as a Performance Data Analyst providing support to Olympic Athletes and Coaches as well as contributing to the wider performance team and working with external partners such as Sheffield Hallam University. Garry provides data analysis of all performance data utilising bespoke software designed and developed in collaboration with SERG producing data stored in Microsoft Azure which is then visualised using tableau software. This involves providing data across disciplines including injury monitoring, athlete wellness, training load and periodisation.

Facilities and equipment

We are located at the Advanced Wellbeing Research Centre in Sheffield's Olympic Legacy Park. This dedicated, state-of-the-art facility provides us with access to world-class research offices, laboratory facilities, workshops, and meeting rooms.

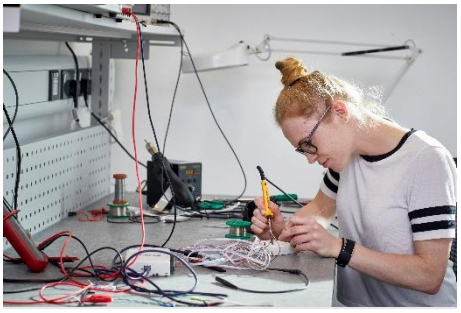


Figure 22: (i) One of five 3D printers housed at AWRC and (ii) a student developing a sensor for their project.

Highlighted laboratories available to us at AWRC

Movement Analysis

This is a vast 500 m^2 space (7.5 m high) and has floor line markings which define the playing space for 8 different sports. It will be the focus for our biomechanics research which will utilise the 26 camera Qualisys motion capture system and 6 AMTI force plates. The motion capture system and the force plates are synchronised and can be used in multiple configurations as required. This allows multiple step and two-foot analysis to be conducted, removing the traditional restraints of a single or double plate configuration.

Design Engineering

The design engineering space focusses on developing a better understanding of sports, medical and physical activity equipment, and environments. Using fundamental physics, experiments, and modelling techniques, we optimise equipment and environments for performance, safety and increased participation. We utilise user centred design to push the boundaries of innovation of equipment, develop prototypes to test our ideas and validate our interventions using advanced measurement systems and analyse.

Innovation Accelerator

The Innovation Accelerator is designed to encourage innovation through its flexible creative space and co-working facilities. Resources include an open office resource for SMEs and start-ups to access accessing specialist kit, facilities, and staff in the Emerging Technologies Hub based within the AWRC. The Innovation Accelerator is the basecamp for SMEs involved in the AWRC Wellbeing Accelerator

Research and Development Workshop

The AWRC has a fully equipped in-house manufacturing and prototype workshop. These facilities are capable of wide-ranging service of in-house fabrication and high-quality precision engineering. We work with a wide range of materials, including bulk metals, foams, plastics and aerospace grade alloys. We offer a range of services from the creation of an initial prototype through to liaison with manufacturers for full production.

Physiology and Human Performance

This laboratory enables us to perform physiological assessments on a high-speed treadmill and high precision cycle ergometer using a range of gas analysis systems. We also have the equipment to assess lung function, cardiac function and record metabolic and hemodynamic parameters. Furthermore, we can measure body composition and bone density, and this testing can be used to conjunction with other equipment in the building such as the human morphology scanning system to provide unique research opportunities.

Electronics Workshop

A dedicated electronics lab at AWRC enables us to showcase our electronics capabilities in circuit design, construction, surface mount rework, prototyping and small production runs as well as advanced testing and diagnostics. We have extensive electronics design expertise including sensor interfacing, wireless data telemetry and embedded microcontroller code. Applications up to now have included sports, human-interface and medical devices. We specialise in the design of low-power wearable or ambulatory devices for use in the field.

Wearable Sensor Development

Body-worn sensors, also known as wearable technology, are a recent development in consumer electronics that are transforming our knowledge of health, sport and physical activity. Widely used consumer examples include Fitbits, heart-rate monitors and GPS watches. This laboratory is equipped with state-of-the-art electronics test and production equipment, allowing the design, manufacture and testing of novel sensors, as well as the characterisation of existing devices.

Morphology

With expertise in the use of traditional methods of human body measurement (anthropometrics) and pioneering applications in 3D imaging technology, we have several commercial 3D imaging systems and the technical expertise which allows us to develop our own systems and analysis techniques.

Highlighted equipment

The AWRC provides us with access to a large bank of specialist engineering and biomechanics equipment that we use to better understand the sporting environment. The equipment allows us to conduct ambitious and complex experiments both in the laboratory and in the field.

The specialist equipment includes:

- Extensive range of high-speed cameras (>50,000 fps and include colour capability) and machine vision cameras.
- XSENS Xbus Kit (MTx motion tracking sensors) and Polhemus Liberty 240/8 electromagnetic motion tracking system.
- Artec Spider and Artec Eva portable 3D scanners, and a range of consumer depth camera scanning systems.
- Shuttlecock, football, cricket and tennis ball launching devices.
- Fully instrumented drop rig (customisable hammers).
- Playing surface rolling profile characterisation equipment.
- Motorised and non-motorised treadmills.
- DEXA Scanner.
- ECG and 16-channel EMG system.

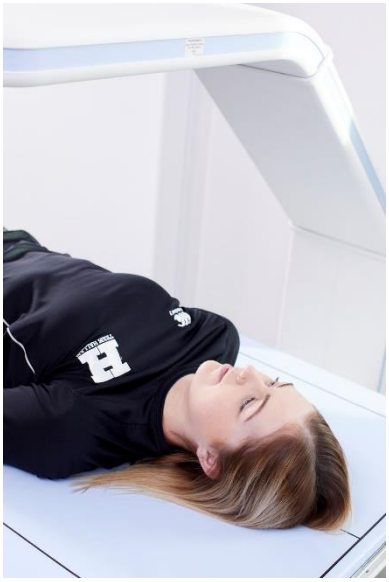


Figure 23: DEXA scanner

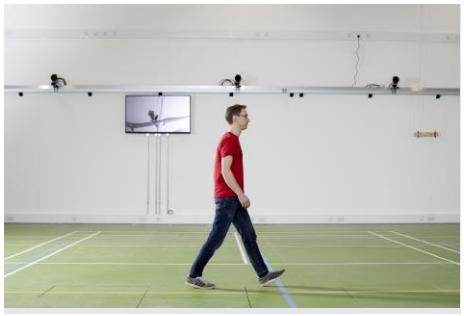


Figure 24: (i) workshop and (ii) participant walking on force plates in Movement Analysis room

Tour of our facilities

PROJECT: MADE TO MOVE FUNCTIONAL MOVEMENT SCREENING (FMS) TOOL

FUNDER: MADE TO MOVE

PRINCIPAL INVESTIGATOR: DR MARCUS DUNN

The initial definition of the problem was to develop a flexible and engaging tool for Rory – Director of Made To Move – to undertake functional movement screening (FMS) with clients. This should be a simple and effective tool, that might offer future commercialisation potential. We met with Rory to discuss exactly what his requirements were with regard to movements that needed to be captured, aspects of the movements to be analysed, and a range of potential hardware and software solutions that he envisaged he might use in practical settings. Subsequently, we undertook a review of existing products and patents to explore what might be possible from a future commercialisation perspective. This, alongside an appraisal of Rory's needs (e.g., simple, portable, durable, and engaging tool) allowed us to refine potential concepts.

One concept device – which incorporated existing hardware was ruled out owing to compatibility issues and risks posed to commercialisation. This led to the refinement of a simplified concept, which relies on a smart phone, a roll-out-mat, and 'puck'. The smart phone application (iOS) uses pose estimation to identify joint locations of clients performing the FMS movements; analysis parameters (e.g., joint angles) are automatically analysed and visualised to the user. The roll-out-mat and 'puck' are used simply to provide measurements of a Y-balance test, where the client stands in a stationary position and pushes their foot as far forwards and backwards as possible. The client simply pushes the 'puck' with their foot, allowing Rory to read off distances (roll-out-mat is printed with a scale to allow this).

The iOS application allows a user to add basic information, introduces each movement in turn and allows the user to take a photo of the client (or use existing photos) to calculate joint angles and FMS scores. The application also allows input of Y-balance scores and provides a summary screen of FMS scores to the user (also exported as a text file for future reference). Rory is currently using the FMS tool and exploring different use cases, such that we can better understand future refinement and commercialisation opportunities of the Made To Move FMS tool.

Figure 25: Example of capturing FMS scores using the Made to Move FMS tool. Users simply take a photo using their smart phone – bespoke FMS metrics are automatically calculated, visualised, and exported.

PROJECT: WEARABLES FOR AGE-APPROPRIATE ACTIVITY MONITORING

FUNDER: INNOVATE UK

PRINCIPAL INVESTIGATOR: DR BEN HELLER

Physical activity and exercise are helpful for the health of older adults and people with long-term health conditions, but only a small number of people do enough regular exercise to make a difference. Wearable devices (such as smart watches) can help people change their behaviour to become more physically active, but most commercial devices are designed to be used by younger people. KiActiv are a company that produce a wearable device that is instead targeted at older people and those with long-term conditions. The aim of this research was to help KiActiv design a next generation device that is more suitable for use by this group, and that targets activities that are important to them.

The biomechanics team at SERG designed a testing protocol to determine the physical effort (energy expenditure and heart rate) required to perform common activities of daily living. Twenty-one participants volunteered to take part in the study, twelve of which had long-term health conditions. The common activities of daily living that participants were asked to perform or simulate were divided into five main categories: walking, food preparation, household chores, gardening, and low intensity exercise. In addition to the measurement of the effort required to perform these activities, we also detect wrists movements with wearable devices.

Using machine learning, we were able to correctly classify the categories of daily living activities with an excellent overall accuracy of 89%. This combined with the energy expenditure and heart rate measurements provided KiActiv with useful information to design a wearable device that is more suitable for older people and those with long-term conditions, and that can ultimately help to improve the health of these groups.

This project was funded by Innovate UK, a public body that supports research, under the Accelerated Knowledge Transfer to Innovate (AKT2I) scheme and was delivered by Sheffield Hallam University in collaboration with KiActiv.

Figure 26: Participants taking part in the KiActiv daily activity monitoring research study at the AWRC.

PROJECT: FEENIXX – OUTDOOR BADMINTON

PRINCIPAL INVESTIGATOR: DR JOHN HART

This summer we were delighted to see the launch of our now licensed outdoor badminton shuttle design, the Decathlon Perfly Feenixx PSC530. The Feenixx shuttle has been developed to allow badminton players to enjoy a high-quality outdoor version of the sport, and in turn to reach a wider audience.

The project was originally conceived between Sheffield Hallam University and Badminton England who had been set tough targets for increased participation. With indoor sports space suitable for playing badminton already at a premium the logical option was to move outdoors. However no credible outdoor version of badminton was available in the marketplace. Shuttles claiming to be suitable for use outdoors, were severely wind affected, or novelty products, preventing a quality game experience for the players. Through the support of a range of funding sources, SERG developed a shuttle that is proven to be less wind affected than traditional designs during outdoor play.

SERG took the shuttle from an initial concept through to a full strength fully functioning injection moulded prototype. Following a period of consumer testing demonstrating the potential of the shuttle, we were able to license this product to Decathlon who completed the industrialisation process and launched the product just in time for the summer holidays.

Figure 27: Decathlon Feenixx outdoor badminton shuttle, designed by SERG, on the shelves in UK, Europe, and Asia, and in play.

PROJECT: HRIG HAMSTRING TESTING DEVICE

FUNDER: DR. MARTIN MCINTYRE, FOOT MOTION LIMITED

PRINCIPAL INVESTIGATOR: DR. BEN HELLER

Dr Martin McIntyre, the founder of The Sports Injury Sports Medicine Clinic, has developed the HRIG device that simulates the mechanism of hamstring injury in sport and provides objective measurements of the user's force production as they perform bilateral and unilateral exercises. It is based on previous research by Martin, the Sports Injuries and Sports Medicine Clinic, Connacht GAA Centre of Excellence and John Moores University and a team from SERG at Sheffield Hallam University.

The SERG team was Dr. Ben Heller, Nick Hamilton, Dr. John Kelley and Dr Chris Hudson who worked closely with Martin to provide hardware design, manufacturing solutions and the software for the device.

Figure 28: Demonstrating the HRIG device.

Dr Ben Heller designed the instrumentation of the device, selecting appropriate load cells to integrate with the leg hooks, and circuit boards to read the load cells and transmit via Bluetooth. The design balanced accuracy, reliability, and ease of manufacturer.

Nick Hamilton completed the product and mechanical design of the HRIG. The device was taken from its prototype stage to manufactured product, considering usability and functionality at all stages. The interface to the user through the leg hooks, their size and shape was crucial to comfort and performance. As well as being easy and comfortable to use, they need to provide a reliable and consistent interface between the user and the instrumentation.

Figure 29: Images of the development of the hooks

Dr. John Kelley developed the iOS app for the HRIG. The app receives the Bluetooth signal and displays the force traces live. The app allows users to create patient profiles, design the prescribed activities for patients, upload data to the cloud and review any of their previously collected data.

Dr. Chris Hudson implemented the security features of the HRIG App that authenticates the user and authorises their data access using their Apple ID.

Figure 30: App user interface

PROJECT: BOCCIA SMARTCOURT

FUNDER: UK SPORT, UK SPORTS INSTITUTE

PRINCIPAL INVESTIGATOR: JOHN KELLEY

Boccia is a Paralympic sport that was specifically designed to allow athletes with high support needs to participate and ultimately compete in elite competition. Because of its design, it is accessible to people of all physical abilities and disabilities, while needing a combination precision, skill and tactics to win.

Boccia UK, supported by the funding of UK Sport and the UK Sport Institute, partnered with Sheffield Hallam University on a multi-year project to produce SmartCourt – a world-leading boccia performance analysis system. The SHU team consisted of John Kelley, Andy Hext and Chris Hudson. Anna Knowles, Biomechanist and Performance Analyst for Boccia UK, describes the system:

"SmartCourt has had a significant impact on the way that performance analysis can best support our athletes and coaches. We can now provide live match reports, immediate feedback for our multi-disciplinary technical analysis, and interrogate our data in a way that has not been possible before now. It is helping us to better understand our sport and provide further insight into boccia performances as we strive for success in Paris 2024 and beyond."

Figure 31: Images from GB Boccia Training Camp using the SmartCourt video review system.

The SmartCourt system has several components. The first allows for video feedback during training that can be used at all the locations used as training camps across the country. This system advanced previous video review systems by providing a portable system that still allows for elite-level athlete feedback and coaching.

The SmartCourt software facilitates and manages data collection from multiple sources, including athlete match and training analysis as well as collecting results and ranking data. The data is stored in a central cloud database. This allows the sport to be much more focused on large scale data analysis.

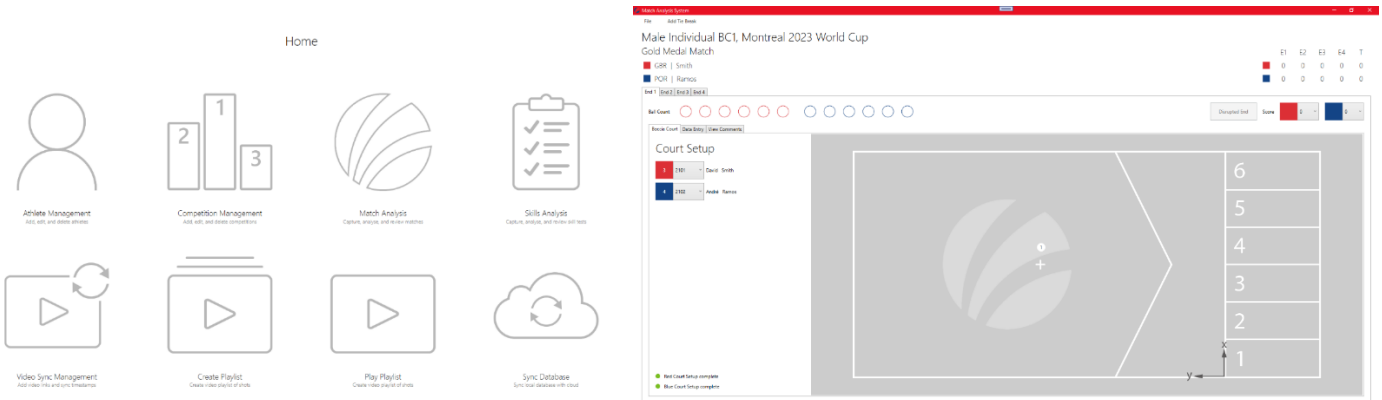


Figure 32: SmartCourt software user interface

PROJECT: COMPUTER SCIENCE IN SPORT

PRINCIPAL INVESTIGATORS: DR SIMON GOODWILL/SHAUN BARRATT

In the dynamic landscape of sports, a notable transformation has unfolded throughout the year. At the Advanced Wellbeing Research Centre, researchers within the Sports Engineering Research Group (SERG) have been diligently working on the integration of sports science and computer science, leading to significant advancements in the realm of athletic performance and personalized training programs. This report provides a comprehensive overview of these developments, shedding light on the intersection of technology and athleticism.

The Role of Computer Science in Sports

Throughout the year, computer science has played a pivotal role in the data-driven world of sports. Athletes, coaches, and researchers have increasingly relied on technology to capture, store, and analyse extensive data related to athlete performance. This data forms the foundation for the creation of personalized training plans, encompassing factors such as nutrition, heart rate, and specialised metrics like ground contact time.

The Convergence of Machine Learning and Computer Vision

One of the key highlights of the year has been the fusion of machine learning techniques with computer vision. Cutting-edge algorithms have been utilised to accurately estimate athlete poses in various sports scenarios, providing insights into force exertion during activities such as boxing. Additionally, these algorithms have been instrumental in counting critical events like kicks and punches during training sessions, enabling a deeper understanding of athletes' technical and tactical approaches.

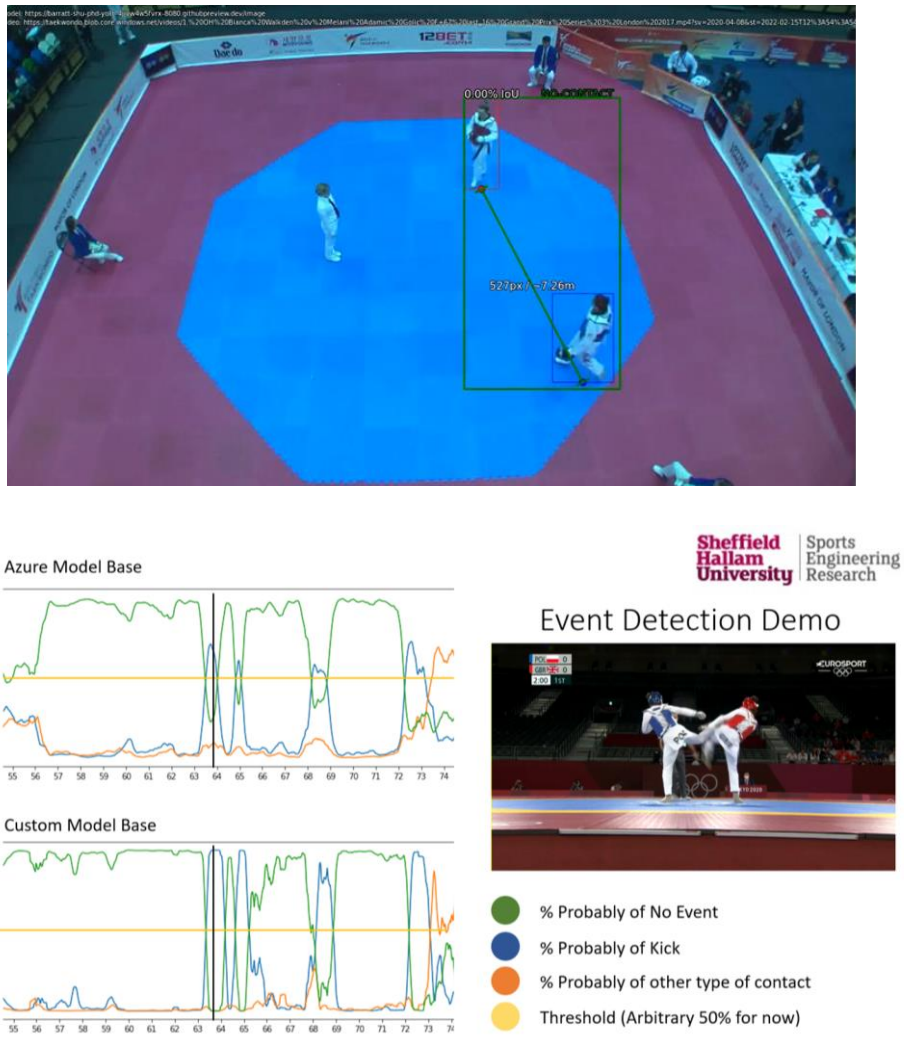


Figure 33: Examples of pose estimation and event detection using machine learning and computer vision algorithms

Impact Beyond Academia

The impact of this research extends beyond the academic sphere. At the Advanced Wellbeing Research Centre, efforts have been made to translate these pioneering studies into practical demonstrations for public engagement, attracting investors and involving local schools. Moreover, physiotherapy has benefited from these innovations, further emphasising the practical implications of this research.

A Vision for the Future

The overarching goal of this transformative research is clear: to equip sports analysts with innovative tools that enhance athlete training to unprecedented levels. Collaborations with experts in biomechanics, data analytics, and design engineering continue to expand the knowledge base, furthering our journey towards sporting excellence.

Fostering Collaboration

Acknowledging the importance of collaboration, this report extends an open invitation to colleagues from diverse academic disciplines. Together, multidisciplinary teams work towards enriching collective knowledge, driving the ongoing revolution in sports.

As we look back on the year's progress at the intersection of sports and computer science, we find ourselves on the verge of a new era. The integration of machine learning techniques and computer vision is propelling us toward a future where personalised training programs and groundbreaking performance analyses are becoming increasingly prevalent. With each step forward, we come closer to unlocking the full potential of athletes and witnessing extraordinary sporting achievements. Embrace the revolution, as the sporting world undergoes a lasting transformation.

Figure 34: SERG student working with athletes and coaches at GB Taekwondo

PROJECT: POWERED ASSISTIVE EXERCISE EQUIPMENT REDESIGN

FUNDER: INNERVA / UK RESEARCH AND INNOVATION (UKRI)

PRINCIPAL INVESTIGATOR: BEN HELLER

Innerva (formerly Shapemaster) manufacture power assisted exercise equipment that uses motors to help users exercise through a full range of motion. Their equipment attracts older adults, those living with long term conditions and people who are intimidated by traditional gym environments.

Innerva have been working with Sheffield Hallam University for several years to better understand the exercise science behind the function of their machines. Sports Engineering have helped them redesign their equipment to allow real-time measurement and feedback of user effort, improvements which have been demonstrated to improve user engagement.

This work has led to funding of £1.1M from UKRI to fund gamification of power assistive exercise under a "Designed for Ageing" award, part of the Healthy Ageing Challenge. The project is called Assistive Gamified Exercise for All (AGE4A) and runs from 2022 until 2024.

Together with SHU colleagues from Design Futures and Physiotherapy, we have investigated the barriers that limit older-people's engagement with power-assistive exercise, and through a co-design process develop innovations that overcome these barriers. We are currently developing a new co-designed user-interface and a digital infrastructure that allows users to set goals, review performance and assess progress. The developed system will be evaluated in leisure centres in early 2024.

Figure 35: Rachel Young (physiotherapist) evaluating the new equipment

PROJECT: PLANET WELLBEING - USING EXTENDED REALITY TO IMPROVE MENTAL HEALTH AND REDUCE LONELINESS

FUNDER: INNOVATE UK

PRINCIPAL INVESTIGATOR: BEN HELLER

One in 15 people aged 50+ are often lonely, rising to one in three for those who are widowed, and one in four for those in poor health. Loneliness and social isolation have numerous health consequences including 26% increased mortality likelihood and more than doubling the risk of developing dementia. Lonely individuals are more prone to both depression and suicide.

Many older people are unable to maintain rewarding in-person connections due to restricted physical mobility or mental health issues such as anxiety or depression. For this group digital engagement via rich, multiuser extended reality games may provide opportunities for deep social engagement and significant agency; however, games are often not designed for older people. We previously developed a user interface that captured older-people's real-world physical actions and used them to navigate a rich virtual world[1]. We showed that older users were able to interact and perform complex activities in the virtual world. By using natural movements, we were able to instil a strong sense of presence.

This work has now received £250k funding from the UK Research and Innovation (UKRI). Working alongside PixelMill Digital and Innerva Healthcare, and together with colleagues from Sheffield Hallam's Centre for Loneliness Studies we are developing *Planet WellBeing* - a virtual world to allow people to use natural physical movements to control avatars performing fun and engaging activities with friends and family and/or strangers in a virtual environment.

We are currently working with older users in a series of workshops to understand their experiences of loneliness, how they view and interact with technology and to design compelling virtual activities. After this phase is complete PixelMill will produce a prototype system which we will then evaluate with users. We hope that the rich social engagement within this world will benefit users' mental wellbeing and reduce feelings of loneliness.

This work has been covered by the BBC News website, The Daily Mirror, the Yorkshire Post, the Sunday Times and BBC Radio 4's PM programme.

Figure 36: Participant interacting with a bespoke virtual environment using a VR headset.

[1] McSeveny, Kerry, Ben Heller, Ann Light, and Katarzyna Karolina Machaczek. "'You could, couldn't you?': A preliminary investigation of older people's interaction with a bespoke virtual environment using a gesture interface." *Journal of Gaming & Virtual Worlds* 5, no. 3 (2013): 235-249.

Dr Tasneem Alnaser

Overuse Shoulder Injuries among Competitive Male Volleyball Players in Kuwait

This doctoral programme established the extent of the overuse shoulder injuries and identified its risk factors in the context of competitive volleyball in Kuwait. This research adopted a pragmatic, mixed methods research design and a revised 'Sequence of Prevention' framework that takes context into consideration. As the first step of the "Sequence of Prevention" model, a high prevalence of overuse shoulder injuries was found, as well as severe impacts on performance, participation, pain, training volume, and task difficulty significantly. As the second step of the "Sequence of Prevention", the multiple risk factors were investigated. Although, there were no significant personal or training-related risk factors, rotator cuff muscle weakness and glenohumeral range of motion deficiencies of external rotation and internal rotation were indicated as a significant physical risk factors of overuse shoulder injuries. In a way to retrieve step one and two of "Sequence of Prevention" model, a qualitative study was conducted using semi-structured interviews with injured volleyball players. Contextual determinants of injury were perceived at multiple stakeholder levels: individual, interpersonal, organizational, and at the policymaker level. The findings are a call to action for translating this research into injury prevention programs that take into consideration the context and levels of the socioecological framework (step 3 and 4 of the sequence of prevention model).

Research Output

Prevalence of overuse shoulder injuries within competitive male volleyball players in Kuwait Study Abstract in the Journal of Sports sciences. To cite this article: (2021) The British Association of Sport and Exercise Sciences Expert Statements, Journal of Sports Sciences, 39:sup2, 1-66, DOI: 10.1080/02640414.2021.1978748

Predictors of overuse shoulder injuries in male Kuwaiti volleyball players: A regression analysis Abstract in the Journal of Sports sciences 2022. To cite this article: Journal of Sports Sciences, Volume 40 Issue sup1, are now available for you to access via tandfonline.com.

Perceptions of overuse shoulder injuries in competitive male volleyball players Abstract in the World Physiotherapy Congress 2023, which takes place from 2-4 June 2023 in Dubai. To cite this article: https://wp2023.world.physio/?_ga=2.115575494.1948752110.1651222898-1956843872.1651222896#/programme/session/da7ad0c0-3ed1-4500-1346-010000000284

Dr Ian Gatt

Effects of Bandaging Techniques and Shot Types on Wrist Motion in Boxing.

Hand-Wrist injuries account for the highest number of injuries in Boxing. Bandaging of the hand-wrist region is a common and historic practice in this sport. However, there is no literature exploring the effect of bandaging techniques on wrist motion in boxing or other combat sports. This programme of research was aimed at improving the knowledge of wrist kinematics on impact in boxing through a rigorous scientific approach.
The programme of research has led to a more detailed understanding of wrist kinematics on impact in boxing with the aim of providing guidance on bandaging that minimises injuries. This work has already been presented to national and international governing bodies – which reinforces how SHU research in Sport and Physical Activity informs policy decisions across the world.

Figure 37: Ian putting his research into practise! Wrapping Chris Eubank Jr's hands before his recent fight with Liam Smith

Research Output

Gatt I, Allen, T., Wheat, J. (2023) Effects of using rigid tape with bandaging techniques on wrist joint motion during boxing shots in elite male athletes. *Physical Therapy in Sport*, 18(61), pp. 82-90.

Gatt I, Allen, T., Wheat, J. (2021) Quantifying wrist angular excursion on impact for Jab and Hook lead arm shots in boxing. *Sports Biomechanics* 6, pp. 1-13.

Gatt, I., Allen, T. and Wheat, J. (2020) Accuracy and repeatability of wrist joint angles in boxing using an electromagnetic tracking system. Sports *Engineering* 23, 2

Externally held positions

Table 2: List of Externally Held Positions

Name	Positions held
Dr Alice Bullas	Deputy Chair of the parkrun Research Board IEEE 3D Body Processing Industry Connections and Standards development group member Member of BSI P9 Ergonomics, ISAK Level 2 Anthropometrist, European Committee for Standardization (CEN) – Anthropometry, British Standards Institute (BSI) – Applied Ergonomics, Dementia Friend and Mencap volunteer Yorkshire Obesity Research Alliance (YORA) Co-ordinator SHU ECR Representative (HRI)
Dr Simon Choppin	Editorial Board of the Sports Engineering Journal Reviewer for the Royal Academy of Engineering's Ingenious programme Participates on the review panel for the UK Council of Graduate Education (for their recognised supervisors accreditation) Associate Editor of Nature: Scientific reports
Dr Marcus Dunn	Advisory Board member: CAMERA 2.0 project (University of Bath) Advisory Board member: British Association for Sustainable Sport (BASIS)
Dr Leon Foster	Member of the Editorial Board for MDPI Topical Collections (Sports equipment and materials) Guest member of the editorial board for MDPI Special Issue (Sports Materials)
Dr Simon Goodwill	Director of the International Sports Engineering Association
Prof Steve Haake	Chair of the parkrun Research Board Chair of the Active Travel Advisory Board Member of the ITF Technical Commission Member of the EIS Technical Steering Pane Member of Sport England Running Collaboratorium
Dr Andy Hext	Deputy Chair of the International Tennis Federation Research Board

Research and knowledge transfer partners

Academic research partners

We forge relationships and collaborate with academic institutions across the world in all areas of our research.

Institution	Collaboration theme
Aalborg University	European Alliance for Sports Engineering Education
King's College, London	parkrun epidemiology, surveying and analysis
La Trobe, Melbourne	parkrun epidemiology, surveying and analysis
Griffith University, Queensland, Australia	Industrial design of Sports equipment
Manchester Met University	Protective sports equipment, swimming biomechanics
Leipzig University	Efficacy of shape analysis as a predictor of health risk
MCI Management Center Innsbruck	Protective sports equipment
National Institute of Education, Singapore	Nonlinear Pedagogy
Purdue University, USA	Biomechanics of reaching
Trinity College, Dublin	parkrun epidemiology, surveying and analysis
TU Chemnitz	Extensive research and teaching collaborations, partner in A4SEE
TU Delft	Extensive research and teaching collaborations, partner in A4SEE
UAS Technikum Wien	European Alliance for Sports Engineering Education
Universidad Carlos III de Madrid	Classification of human movement
University of Jyvaskyla	Affordances in children's motor learning to impact on STEAM learning, physical activity and biomechanics
University of Lisbon	Theoretical frameworks for ecological dynamics in sport / team games processes in elite and development sport
University of Porto, Portugal	Talent development and expertise acquisition in sport
University of Portsmouth	Breast biomechanics
University of Rouen	Coordination of action in individual sports such as climbing and swimming, extensive teaching collaborations
University of Sheffield	Stroke rehabilitation; parkrun epidemiology, surveying and analysis, digital health
University of Sydney, Australia	parkrun epidemiology, surveying and analysis
University of St Cyril and St Methodius	Affordances that regulate action in sport performance and learning
University of Tennessee, USA	Biomechanics of running
University of Valencia	Running injury and footwear
VU Amsterdam	Athletic Skills Model (ASM), coaching and training frameworks for elite and developing athletes

Knowledge transfer partners

Each year we establish new knowledge transfer partnerships as our portfolio of work grows. Alongside these new partners, we have long standing relationships with many companies and institutions.

2022/23	Recent
adidas	Badminton England
Advertising Standards Agency	Beta Climbing
Babolat	Birmingham City Council
Boccia UK	Braintrain2020 Limited (SleepCogni)
Bowls Scotland	Club Together
British Amateur Boxing Association	Consolite
British Army Boxing	Crown Hockey
British Athletics	Derby Teaching Hospital NHS Foundation Trust
British Equestrian Federation	England & Wales Cricket Board
British Cycling	Football Association
British Gymnastics	Footfalls and Heartbeats
British Para Swimming	Gilbert Rugby
British Sailing Team	Goalfix Sport
British Swimming	Grays International
Clearcast	Gunn & Moore
Decathlon	hero
England Athletics	HD Sports
English Institute of Sport/UKSI	HP1 Technologies Ltd
Etexsense	London Sport
EXYO	Manchester City Council
Foot Motion Ltd	Mayathon
FIFA	Mayor of London
GB Boxing	Metropolitan Police
GB Canoeing	Mitre Sports
GB Diving	Mountain Training Trust
GB Rowing Team	National Centre for Sport & Exercise Medicine
GB Taekwondo	New Balance
Golf In Society	New Balls
Golf Pride	On Running
Harworth Estates	Ping
Ineos Grenadiers	Planet X Bikes
Innerva (formerly Shapemaster)	Puma
International Tennis Federation	Reebok
International Sports Engineering Association	Rounders England
Innovate UK	Royal Academy of Engineering
JR286	Royal Yachting Association
JT Rehab	Run3D
Keele University	Sheffield Children's Hospital
Labosport UK	Sheffield City Council
Leeds University	Sheffield City Region
Martin McIntyre	Smiths Medical
Metropolitan Police	Speedo International
Mitre	SportScotland Institute of Sport
Royal Yachting Association	Sports Turf Research Institute
Runscribe	Tencate
Sheffield Teaching Hospitals NHS Foundation Trust	Wasp Hockey
Sportable	University Hospital Ghent
Sportcor	Welsh Boxing
Tectores Ltd (PelliTec)	Westfield Health
Targetbound	World Rugby

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