INTERACTIVE BIOMECHANICS AND ELECTRONIC TEXTILES

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This paper presents an overview of a wearable interactive system developed by CSIRO that uses electronic textiles to enable interactive biomechanical measurement and feedback. Textile strain sensors are used to measure limb motion with real-time data streaming and analysis that enables interactive feedback to assist with skill acquisition. The system can be used in diverse training and competition environments, as illustrated via examples in kicking, throwing and paddling.

KEY WORDS: interactive textiles, skill acquisition, kicking, kayaking, throwing.

INTRODUCTION: Accurate and reliable measurement of skills and skill development is typically limited to a laboratory setting or simplified performance environment using motion capture systems. Electronic textile sensors (Carpi & DeRossi 2005), such as strain sensors, are enabling measurement in a way that allows motion capture and real-time feedback in diverse training and competition environments. When shown to have sufficient accuracy and reliability (Helmer Mestrovic, Farrow, Lucas & Spratford 2008; Helmer, Farrow, Lucas, Higgerson & Blanchonette 2010; Helmer, Farrow, Ball, Phillips, Farouil & Blanchonette 2011), electronic textile technology affords new opportunities for monitoring and training in the performance environment. This paper presents an overview of recent studies using the CSIRO Wearable Interactive System (WIS) for three different skills.

METHODS: Electronic textile garments were prepared by fixing electronic textile strain sensors onto a well fitted host garment to examine kicking, throwing and kayak paddling skill respectively:

- Kicking skill: the host garment was a pair of compression leggings commonly worn in sports training, and strain sensors were fixed onto the garment across the anterior aspect of the knee joint, with the sensor running along the longitudinal axes of the thigh and shank segments.
- Kayak paddling skill: the host garment was a long sleeve compression shirt, and textile strain sensors were placed on each elbow across the anterior aspect.
- Throwing skill: the host garment was a custom made elastic sleeve that covered the elbow and wrist joints, and the strain sensors were placed across the anterior aspect of the elbow and wrist joints, with the sensor running along the longitudinal axes of the arm.

The three garments are shown during use in Figure 1.

Figure 1. Electronic textile garments used for (a) kicking, (b) kayak paddling, and (c) throwing.

A custom wireless electronic transmitter streamed measurements from the strain sensors in real-time to a computer located nearby. Customised logging and feedback software developed using National Instruments LabVIEW™ suite running in Windows XP®, was used to capture performance data and to provide real-time interactive biofeedback in certain tests. The auditory biofeedback was played through a speaker located near the subject.

RESULTS AND DISCUSSION:

Garment validation and kicking: The ability of the CSIRO WIS leggings (i-Leggings) to reliably monitor leg motion was assessed for a set of exercises involving running and kicking (soccer, rugby and Australian football kicks) in a motion capture laboratory. Knee angle data from participants were measured using the CSIRO WIS and Optotrak Certus systems to ascertain whether any significant differences exist in knee angle data derived from the two measurement systems. Results of a range of lower limb tasks including kicking suggested the WIS leggings performed very well when compared to the Optotrak Certus system, (R^2 range 0.91 - 0.98), and was consistent with previous studies comparing similar garments on other limbs with a Vicon system (Helmer et al. 2008). Figure 2 shows an example of a comparison for a kicking event.
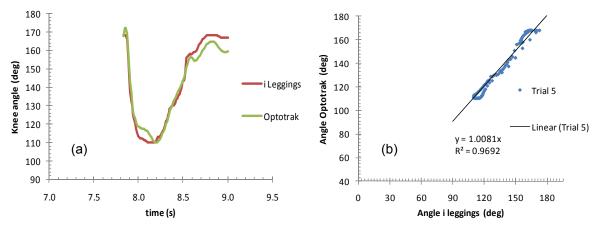

Figure 2. Comparison of i-Leggings and Optotrak kinematic data for a maximal effort during Australian football kicking task (a) knee angle vs time, and (b) Optotrak vs i-Leggings, for a typical trial.

The leggings were found to be a valid tool for the real-time measurement and interpretation of key lower limb angles when running and kicking footballs. The freedom of movement allowed by the garment based system permitted running and kicking performance to be measured and biofeedback provided within the natural performance environment. Further research exploring the role of feedback modality and learning is in progress.

Integration of biomechanics with output measures and kayak paddling: The ability of the CSIRO WIS shirt to monitor arm motion and contribute to paddling technique assessment was explored in a typical field setting. Additionally, an accelerometer was externally mounted on the kayak to measure the acceleration of the boat and a force sensor was mounted on the bottom of each paddle blade. The sensors were synchronised in a common wireless data acquisition system. Time series paddler technique data was recorded and Figure 3 shows a comparison of the elbow angles during the stroke cycle for an elite and novice kayaker along with other performance metrics. A number of technique issues and performance measures of interest (Baker, Rath, Sanders & Kelly 1999), such as stroke rate, stroke duration, depth of blade immersion and stroke symmetry were also obtained. This enabled real time insight into paddling technique and the development of feedback information to improve technique.
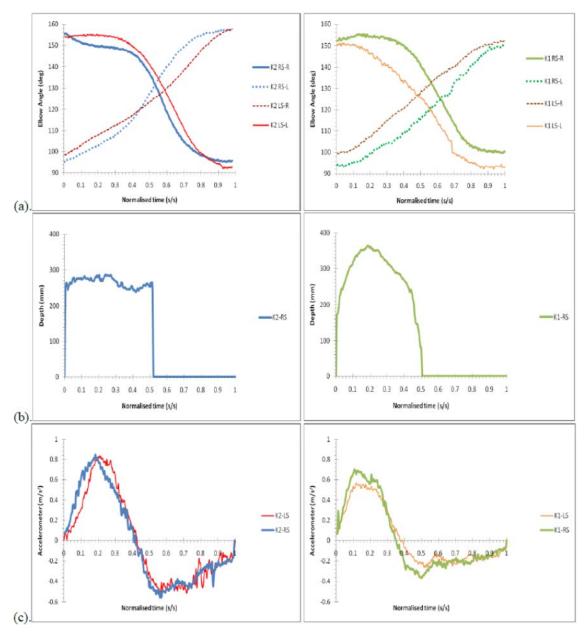

Figure 3. Average of 10 strokes with normalised stroke time (a) Left (-L) and right (-R) elbow angles during right strokes (RS) and left strokes (LS) (b) Right stroke paddle depth, and (c) Boat acceleration from right strokes (RS) and left strokes (LS) for *Left* elite kayaker (K2) at 70 strokes/min, and, *Right* experienced novice kayaker (K1) at 84 strokes /min.

Interactive feedback and throwing: Auditory biofeedback can present new information related to spatial and/or temporal aspects of movement. The CSIRO WIS sleeve was used to

monitor arm motion and subsequently provide auditory bio-feedback so as to assist novice technique development in a training setting where there was no expert guidance. Figure 4 shows an interactive biomechanics model for preferred elbow and wrist motion during an adapted netball shot at goal and includes an overlay of interactive rhythmical percussive biofeedback. The preferred movement pattern is defined by threshold angles that play specific audio samples when triggered – for the elbow this was set at approximately $90°$ (for loading up) and for the wrist $15°$ past vertical (for follow through).
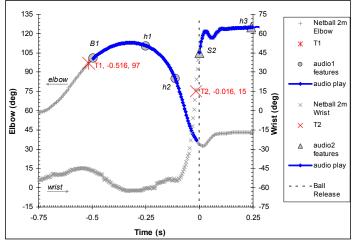

Figure 4. Typical relationship of elbow and wrist angles for an adapted netball shot at goal, with interactive trigger points (T_1, T_2) and rhythmical feedback audio features (B_1 bass drum, H_{1-3} hihat, and S_1 snare drum) during sound play highlighted. The ball release occurs at t=0.

The application of interactive biomechanics to a novice group encouraged greater movement exploration during task training (Helmer et al. 2010), which is associated with effective learning (Newell 1985). This study provides preliminary evidence for a general improvement in throwing accuracy and highlights the potential of interactive biomechanics to significantly affect technique development and accelerate learning. Whilst there is scope for improvements to fit and function of electronic textiles across a population (of various shapes and sizes), the study demonstrated potential for their use as a field based testing and training tool.

CONCLUSION: Wearable sensor systems and real-time data streaming are enabling widespread field measurement of biomechanical information. This capability can be combined with other measures and movement knowledge for the rapid assessment of performance including the development of interactive biomechanics models to enhance skill development.

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