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PRELIMINARY DEVELOPMENT OF A RECONFIGURABLE GARMENT SYSTEM FOR INTERACTIVE BIOMECHANICS

Richard Helmer[1], Ian Blanchonette[1], Damian Farrow[2,3], Kevin Ball[2], Callum Mackay[2]

[1]CSIRO Materials Science and Engineering, Belmont, Victoria, Australia
[2]ISEAL, Victoria University, Melbourne, Victoria, Australia
[3]Australian Institute of Sport, Canberra, ACT, Australia

This paper presents a garment system that uses electronic textile strain sensors attached to a host garment to enable interactive biomechanical monitoring and biofeedback. A conventional compression garment modified to include strategically placed fastening markers and a corresponding e-textile strain sensor were used to monitor knee flexion and extension during AFL kicking. The output of the garment system was compared with that of a Vicon. During repeated subject kicking the garment system displayed stable operation suggesting it was suitable for use in field based skill interventions involving interactive biofeedback.

KEY WORDS: interactive textiles, skill acquisition, kicking.

INTRODUCTION: Mobile and wearable systems with real-time data streaming are enabling widespread field monitoring and feedback of important biomechanical and performance information (Helmer, Blanchonette, Mestrovic, Abdulla, Taylor & Martin 2012). Electronic textile sensors, such as strain sensors, are enabling this in a way that affords new opportunities for implementing interactive biomechanical biofeedback as part of skill interventions in the natural performance environment. For example, e-textile devices are well suited to monitor limb flexion and provide immediate biofeedback and so can be used to increase flexion, ideally by a certain amount, as suggested by studies with AFL kicking where such a change in technique may be desirable to improve kicking (e.g. to kick a lower, faster kick) (Baker & Ball 1996). Recent studies with e-textiles have suggested there is scope for improving the fit and function of electronic textile garments to improve sensor performance and to increase the versatility of this technology for use with diverse populations and skills (Helmer, Farrow, Lucas, Higgerson & Blanchonette 2010). The use of garments with fully embedded sensors, whilst ideal for particular subjects, is less suited to diverse populations. As more sensor garments are required, the entire garment has to be replaced if damaged, leading to significant interruptions, and often a new garment is required each time a particular aspect of motion is to be studied. As such, a garment system that uses re-locatable strain sensors that can be attached to various locations on a set of host garments of various sizes with a common configuration for attaching the strain sensors is desirable. This paper presents a preliminary study to explore the performance of a garment system using re-locatable strain sensors during realistic operation. In particular, the potential to directly measure joint angles during AFL kicking.

METHODS: The host garment was a pair of compression leggings (2XU) commonly worn in sports training modified to include a set of three male press fasteners in an evenly spaced, linear configuration across the anterior aspect of the knee joint, so that an e-textile strain sensor could be located along the longitudinal axes of the thigh and shank segments. Stand alone electronic textile strain sensors, similar to those used in previous studies (Helmer, Farrow, Ball, Phillips, Farouil & Blanchonette 2011) but narrower and with three female press fasteners evenly spaced along the sensing region, were prepared so that they could be attached to the host garment's matching set of male press fasteners. Host garments in various sizes (e.g. small, small tall, medium) were prepared so that athletes could choose a garment size. The electronic textile garment system incorporating a host garment with re-locatable strain sensors for monitoring knee movement is shown during use in Figure 1.

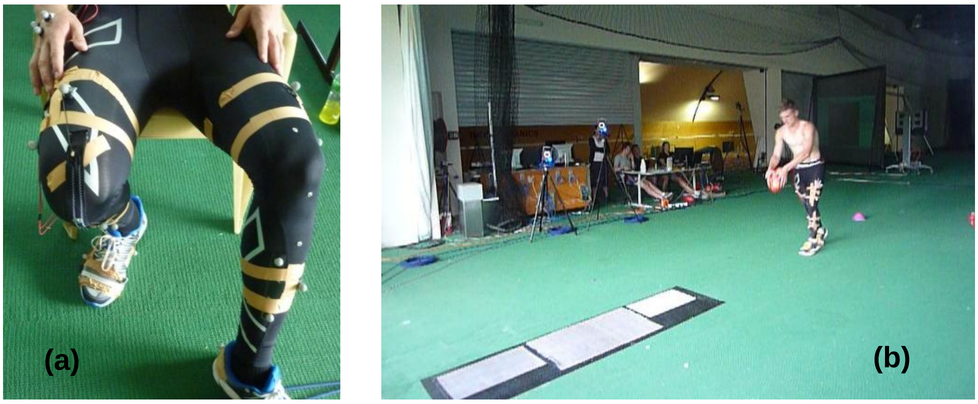

Figure 1. Subject wearing the electronic textile garment system incorporating a host garment with re-locatable strain sensors for measuring knee flexion and extension during AFL kicking.

The performance of the garment system was studied on an AFL athlete, (male age 18 years, size M) using their 'natural kicking action' for a 35m kicking task. The subjects wore both the garment system and a set of markers for the Vicon motion capture system on their preferred kicking leg and other regions of their body to explore how the two systems (Vicon and garment) compared. A custom wireless electronic transmitter streamed measurements from garment sensors in real-time at 500Hz to a nearby computer. Customised logging and feedback software developed using National Instruments LabVIEW™ suite running in Windows XP®, was used to capture performance data. Lower body kinematics were recorded using a cluster based marker set. Joint centres as defined by anatomical markers during the static trial were stored in technical coordinate systems for each segment. The Vicon captured data at 250Hz and linear interpolation was used to achieve a common sample interval of 500Hz for direct comparison with the garment system. The point of maximum knee flexion was used to synchronise all kicking exercises to a common time.

RESULTS AND DISCUSSION:

Garment validation and kicking: The Vicon motion capture system is considered the gold standard for accuracy and precision for sport [4]. Figure 2 shows an example of primary data captured from (a) Vicon and (b) garment systems.

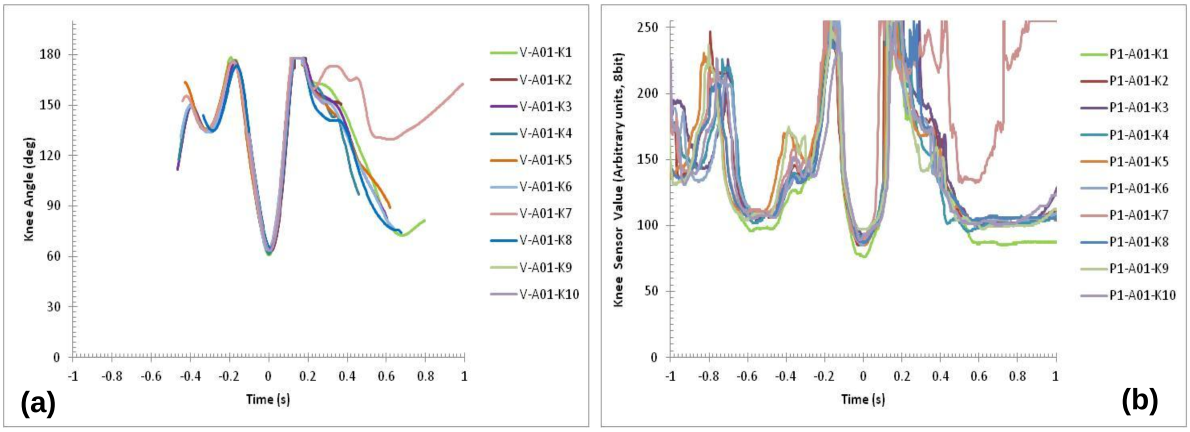

Figure 2. Primary limb movement data for 35m Australian football kick (a) Vicon, and (b) garment system.

The location of markers and placement of sensors is a key factor in accurately capturing motion. Results suggested the garment system and its location of attachment points across the knee has promise for use during repeated subject kicking with stable operation evident when compared to the Vicon system, see Figure 3.

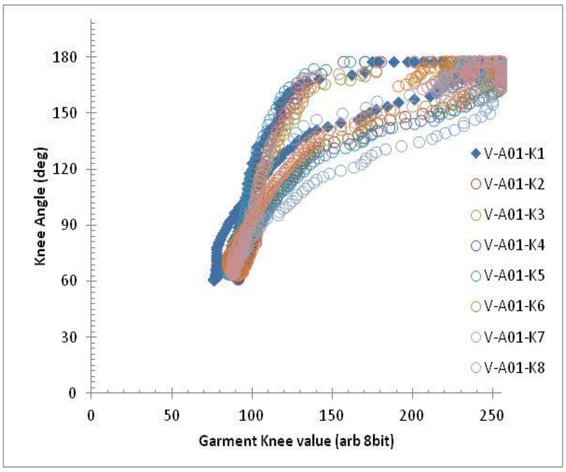

Figure 3. Calibration of garment system with Vicon and average kick for movement pattern Australian football kicking task Vicon vs garment system.

Some signal hysteresis was present during positive and negative strain resulting from flexion and extension of the knee. This means that achieving a coherent calibration that has meaning for both flexion and extension is challenging although quite meaningful calibrations can be achieved for particular aspects of motion as evident for the flexion aspect of an AFL kick as shown in Figure 4. This was generally consistent with previous studies involving similar sensors completely incorporated into garments (Helmer, Mestrovic, Farrow, Lucas, & Spratford 2008). It is plausible the method of sensor attachment resulted in a slower sensor response during negative strain of knee extension (i.e. the garment system recovered more slowly in the extension phase).

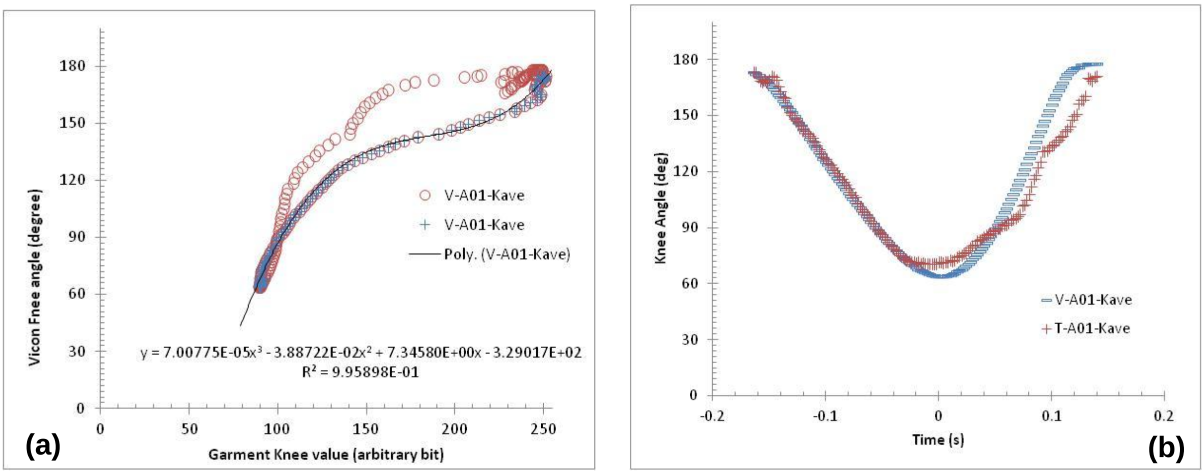

Figure 4 (a) Garment Calibration using flexion component of movement and, (b) comparison of associated knee angle derived from sensor and Vicon analysis.

Considerations for interactive biofeedback interventions using garment systems:

Whilst absolute measurement remains challenging for e-textile based systems in field settings, the good repeatability and stability of the garment system suggests it can be used for meaningful biomechanical intervention but this needs to be carefully considered. Knowledge of an interactive system's strengths and weakness and the intended movement scenario is important to use the garment system. So long as the relationship between the host garment, textile sensor and subject is maintained (i.e. the 'markers' are not disturbed), a good correlation with particular aspects of motion between the two systems can be achieved, particularly for flexion. Points to note from this preliminary trial include:

- Be mindful of which aspect of motion is of interest and attribtues of sensor (e.g. different calibration for flexion and extension)
- Perform warm up excises that reflect the nature of the task for a duration that enables the garment to stabilise on the subject and watch for subject manipulation of garment
- Offer subjects a range of garments so athletes can select a garment that fits them well and is perceived to be comfortable and consistent with their routine training attire
- Use a secondary measurement means (e.g. Vicon or video) for key measurements as part of key elements of intervention protocol (e.g. pre test and post test)
- Prior to intervention, perform a validation trial and collect mulitple samples of natural movement with garment system alongside an established motion analysis system to develop a representative generalised movement and interactive model for representative population

The garment system used here was found to have promise for the real-time monitoring of key lower limb angles during kicking footballs. Whilst the particular compression leggings used in this study, when chosen to fit well, appeared to have performance attributes suitable for use as part of a reconfigurable garment system for interactive feedback, other manufacturer's leggings with similar design features might also serve as valid host garments. Further research exploring the role of feedback and skill interventions in AFL kicking using sensor garment systems is in progress.

CONCLUSION: A well fitted compression garment with strategically placed fastening points and matching e-textile strain sensors can be used to monitor movement and is suitable for use as part of an interactive device for skill interventions involving interactive biofeedback based on biomechanical insight.

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