Soft-robotics wearable device for rehabilitation of Achilles tendon rupture

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MOTIVATION AND AIMS

Motivation
Achilles tendon rupture affects 4500 people per year in the UK alone(3). The current non-surgical protocol for rehabilitation involves wearing a functional orthosis for up to 16 weeks(4). This limits the range of motion of the ankle and is adjusted depending on the time since injury. There is a wide demographic of people who rupture their Achilles tendon and they all have very different recovery times, therefore the current time based approach can lead to re-injury, muscle atrophy and immobility.

Overall aim
The overall aim of this project was to create a wearable device to track the range of motion of the ankle. This would allow for patients with Achilles tendon ruptures to be provided with specific, personalised rehabilitation programs to optimise recovery. This builds on a previous 4YP(5) in which a prototype of an instrumented sock to monitor ankle motion was created. The wearable device had two parts, a compression sock to test the extension of the sensors and a data collection unit containing a sensor attachment and a data logger. The device then had to be tested on human participants to see if ankle angle could be estimated from the instrumented sock data.

DESIGN EXPERIMENTS

Sensors attachment
An experiment was carried out to investigate the best method of attachment. An Intron material testing machine was used. Three samples were tested, each one made up of a sensor attached with a different method to a piece of sock material:

Sample 1 - fabric glue and zig-zag stitching around the perimeter
Sample 2 - zig-zag stitching around the perimeter
Sample 3 - zig-zag stitching around the perimeter and straight reinforcing stitches at the ends

The samples were stretched to a preload force of 1N to ensure they were under tension, then increased in increments of 10mm, up to 50mm extension. The extension of the entire sample and the extension of the sensors were measured at each increment.

Spring models were used to find that sample 3 had the lowest value of both and it; therefore restricting movement as minimally as possible. A graph of sensor extension vs whole sample extension was also plotted, revealing the highest gradient for sample 3 - suggesting it is the most responsive sensor to movement. Sample 3 was chosen as the best attachment method.

PROTOTYPE TESTING

Testing aims
The aim of testing the prototype was to use a motion tracking system to collect kinematic data while simultaneously recording sensor outputs from the instrumented sock during a range of movements. This would allow for comparison between sensor outputs and ankle angles - correlations could be investigated and mappings between values made.

Motion Capture
The motion tracking system used was the Vicon in the Oxford Gait Laboratory. There are 12 motion capture cameras that detect the 3D position of small reflective spheres that are stuck on the body in specific anatomical locations. The Vicon Polygyn software has model pipelines that use the detected markers to define segments and joint centres, which allow for calculation of joint angles.

Testing Protocol
The instrumented sock was worn on the participant’s right foot. Reflective markers were placed using double sided tapes in the correct anatomical locations for the Oxford Foot Model and Lower Body Plug In Gait Model(2) - these allow for calculation of ankle angles.

Data collection was started on both the Vicon and the instrumented sock, before a range of movements were carried out, these movements were chosen to cover a large range of motion and were:

- Static: standing still for calibration
- Non-weight bearing (seated): plantar-dorsiflexion, inversion-eversion, circumduction
- Weight bearing (standing): heel lift, heel lift hold, inversion-eversion, squat
- Walking: standard gait

RESULTS

Data collected during the prototype testing was used to create linear mappings between sensor outputs and ankle angles for plantar/dorsiflexion and inversion/eversion. The sensors were only used for mappings for the ranges they were in extension for.

CONCLUSION

A prototype of an instrumented sock to track ankle motion was successfully made and tested, revealing the potential for development with this technology. Models were trained to see if ankle angle could be estimated from the instrumented sock sensor outputs, these showed good estimations of ankle motions but improvements need to be made to the accuracy of specific ankle angle estimation. This could be done through collecting large data sets with motion capture and developing machine learning techniques to map between the collected data and kinematic joint angles.

REFERENCES